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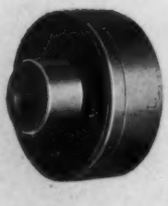

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GAS MIXING and DISTRIBUTION

at Great Lakes Steel Corporation

By W. H. COLLISON
Assistant Superintendent Coke Plant

and F. C. FRYE
Fuel Engineer

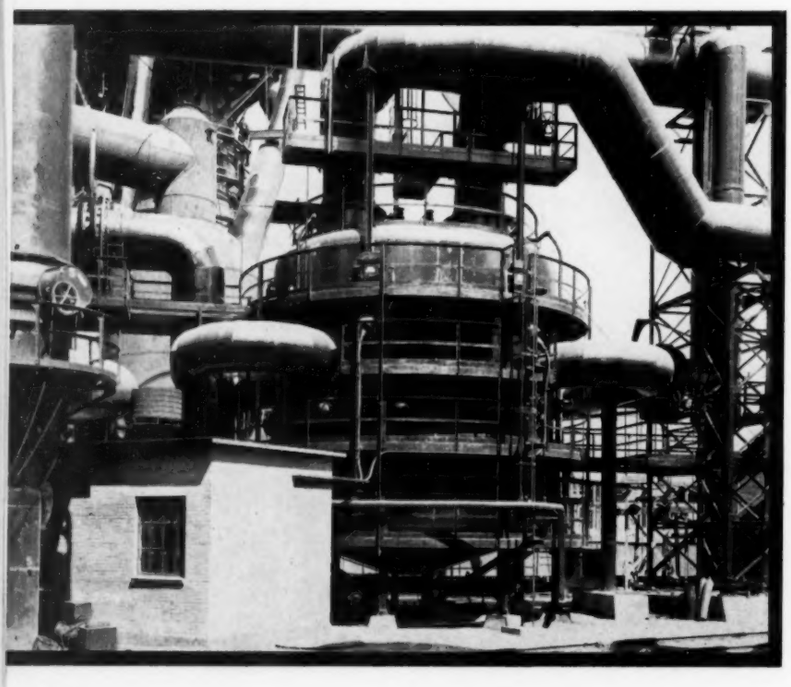
GREAT LAKES STEEL CORPORATION, ECORSE, MICHIGAN

Presented before A. I. S. E. DETROIT SECTION, May 12, 1940

▲ HEAT is required in almost every step in the making of steel and the cost of the fuel required is one of the major items in the cost of producing the steel. Steel companies operating blast furnaces and coke ovens find it necessary to utilize to the fullest extent, the by-product fuels, blast furnace gas and coke oven gas. Bleeding, or wasting these gases to the atmosphere, incurs not only a financial loss but also a considerable nuisance.

The expansion and modernization of Hanna Furnace Division of Great Lakes Steel Corporation by the construction of a third furnace, a modern boiler house and blowing room and a new coke plant, made available substantial quantities of both blast furnace and coke oven gas. Accordingly, provisions for cleaning, mixing and distributing these gases were made, which will be described, along with the steps taken to meet variations in supply and demand.

FIGURE 1—Electrical precipitators are used for fine cleaning of blast furnace gas after the conventional dust-catchers and washers.



BLAST FURNACE GAS

The blast furnace is well known as a producer of large volumes of low grade gas. The production at Hanna Furnace Division averages 272,720,000 cu. ft. per day when three furnaces are making 2,220 tons of iron and consuming 1,948 tons of coke. Typical analyses of this gas are shown in Table I.

TABLE I

Typical Gas Analyses

	Blast furnace gas	Coke oven gas	Mixed gas to mill	Diluted coke oven gas	Enriched blast furnace gas
Carbon dioxide, CO_2	14.3	1.5	5.5	4.1	11.5
Illuminants	0.0	3.5	2.3	2.6	0.0
Oxygen, O_2	0.0	0.3	0.4	0.2	0.2
Carbon monoxide, CO	25.0	6.6	14.5	12.0	26.8
Methane, CH_4	0.2	30.6	16.9	23.2	0.5
Hydrogen, H_2	2.4	55.5	35.3	42.5	3.6
Nitrogen N_2	57.7	2.0	25.1	15.4	57.4
Specific gravity	1.01	.36	.61	.52	1.0
Btu. per cu. ft.	92	565	370	450	100
Coke oven gas, per cent	0.0	100.0	60.0	75.7	1.7
Blast furnace gas, per cent	100.00	0.0	40.0	24.3	98.3

Dirty blast furnace gas is unsatisfactory for several reasons. It will obstruct checker openings in blast furnace stoves and coke oven regenerators; it may cause the fluxing of silica brick in coke ovens and it will foul boosters and mains. To meet the requirement of .015 grains dust per cu. ft. or less, the gas is cleaned by five

electrical precipitators after the conventional dust catchers and washers.

Briefly, the precipitator removes dust from gas by the silent discharge of a high voltage uni-directional current, from an electrode in the center of a tube, to the walls of the tube. Dust particles become charged and are repelled from the electrode to the walls of the tube where they are wetted and washed away by a film of water trickling down. The voltage used is approximately 75,000. The tubes are 8 in. diameter by 15 ft. long and may be expected to have an efficiency of 97 per cent at 200 cu. ft. per minute or 95 per cent at 240 cu. ft. per minute.

Precipitators No. 4 and 5 clean the gas from the washer of "A" furnace. These precipitators have 120 tubes each. Gas cleaned by these units is divided between "A" furnace stoves, the boiler house and No. 1 booster station. Precipitators No. 1, 2 and 3 clean the gas from a common header into which the washers of "B" and "C" furnaces discharge. No. 1 and No. 2 each have 252 tubes. No. 1 cleans the gas burned at "B" and "C" furnace stoves. No. 2 cleans the gas which goes to the main header at the boiler house.

No. 3 precipitator is considerably larger than the others because it cleans the blast furnace gas to the coke ovens and No. 2 booster station. It is divided into halves which may be operated independently to permit cleaning without too serious loss of capacity. Each half has 176 tubes. This precipitator has been operating at an efficiency of 95 per cent and .015 gr. maximum dust per cu. ft. in the cleaned gas. The power consumption is about 36 amperes at 260 volts. Because of the importance of this precipitator, lights have been placed in the exhauster room of the by-product plant to signal power failure.

A gas holder of 1,500,000 cu. ft. capacity after No. 3 precipitator absorbs some of the variations in blast furnace gas supply and demand but its primary purpose is to provide a reserve supply of gas to be used while making the changes necessary when furnace shut-downs or other emergencies arise. The holder is of the "waterless" type. A piston floats up or down, according to the supply of gas, within the shell which is 115 ft. diameter by 170 ft. high. This piston is sealed around its entire circumference by a special holder seal lubricant supplied by reservoirs to a lubricant space between two layers of packing. Each packing layer is made of three plies of continuous elastic fabric. The piston is weighted to give a holder pressure of 12 in. of water gauge. The astonishing amount of 150 tons of concrete blocks, in addition to the weight of the piston proper, is required. A cable fastened to the piston operates an indicator on the side of the holder which is calibrated in thousands of cu. ft. in the holder and through a selsyn motor, gives this information to the gas dispatcher at No. 2 booster station, the heaters at the coke ovens and the operators in the by-product building. Eleven emergency "blow-off" pipes or bleeders, which are opened at 1,540,000 cu. ft., protect against over-travel of the piston.

Normal protection against over-travel is by three means. The first is control of flow to the holder by means of a butterfly valve in the 72 in. inlet main; this is motor operated and push-button controlled from the by-product building. The second is an automatic control attached to the piston height cable which closes the same butterfly valve at 1,350,000 cu. ft. and will not permit reopening until the piston has dropped below that point. The third is an automatic bleeder at No. 3 precipitator which opens at a set pressure, 32 in. of water.

Precautions against piston travel to the rest blocks at the bottom are also three. The first prevents back flow to the precipitator by closing the butterfly valve

FIGURE 2—The gas holder, of the waterless type, has a capacity of 1,500,000 cu. ft. of blast furnace gas.

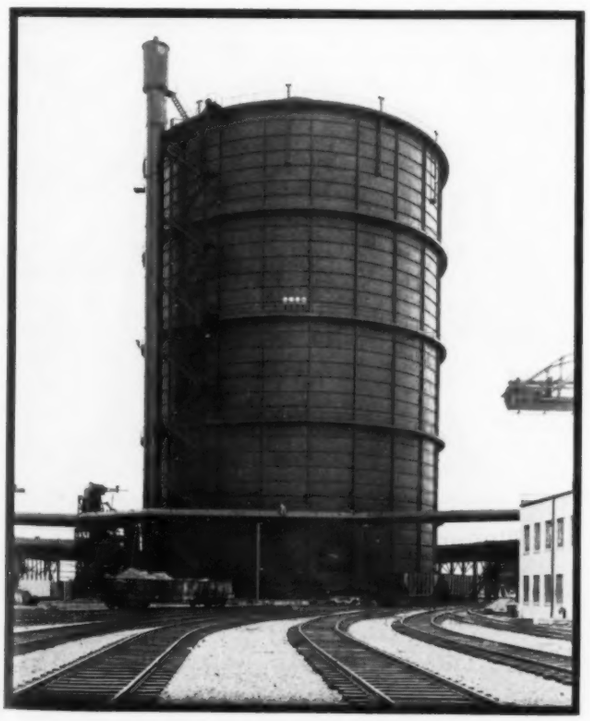
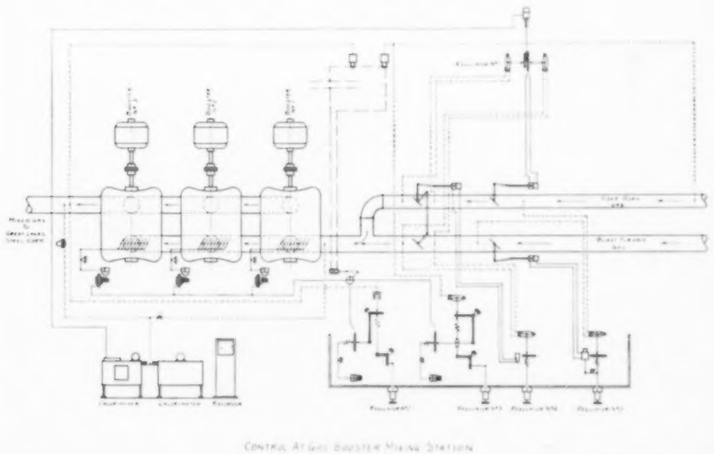


FIGURE 3—Schematic diagram showing control equipment for mixing coke oven gas and blast furnace gas.



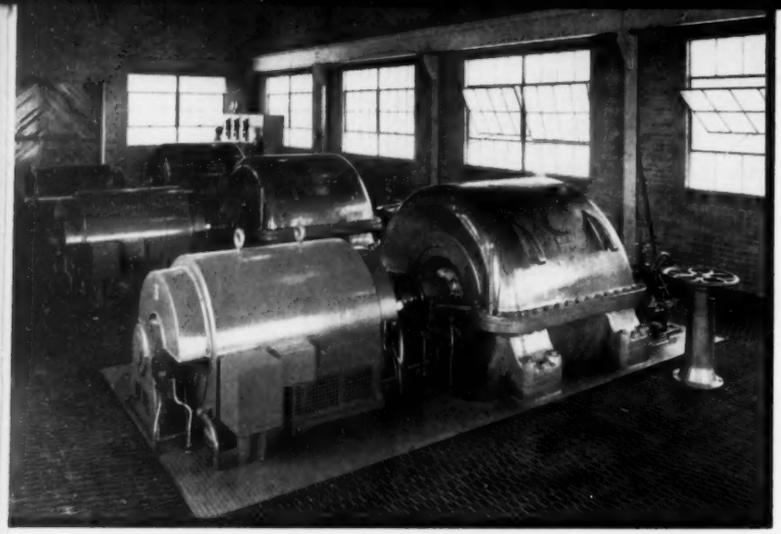


FIGURE 4—View showing the centrifugal compressors, of 27,000 cu. ft. per min. capacity each, indicated in Figure 3.

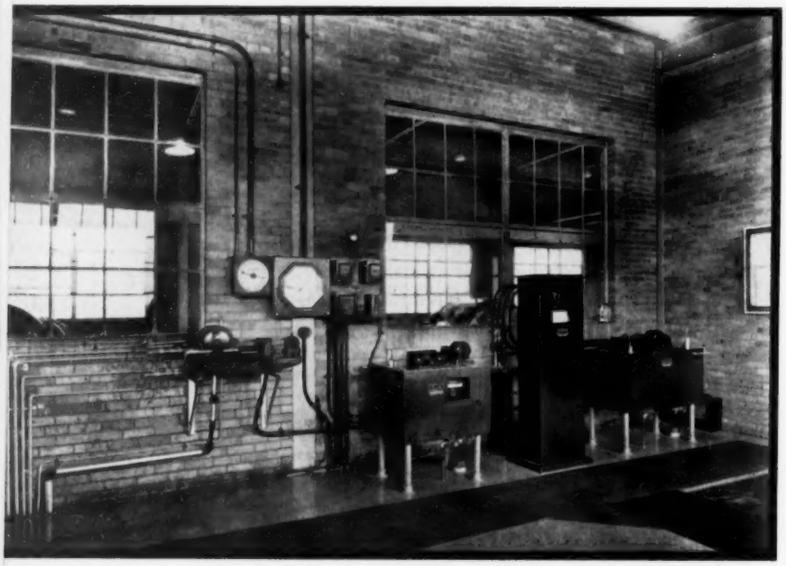
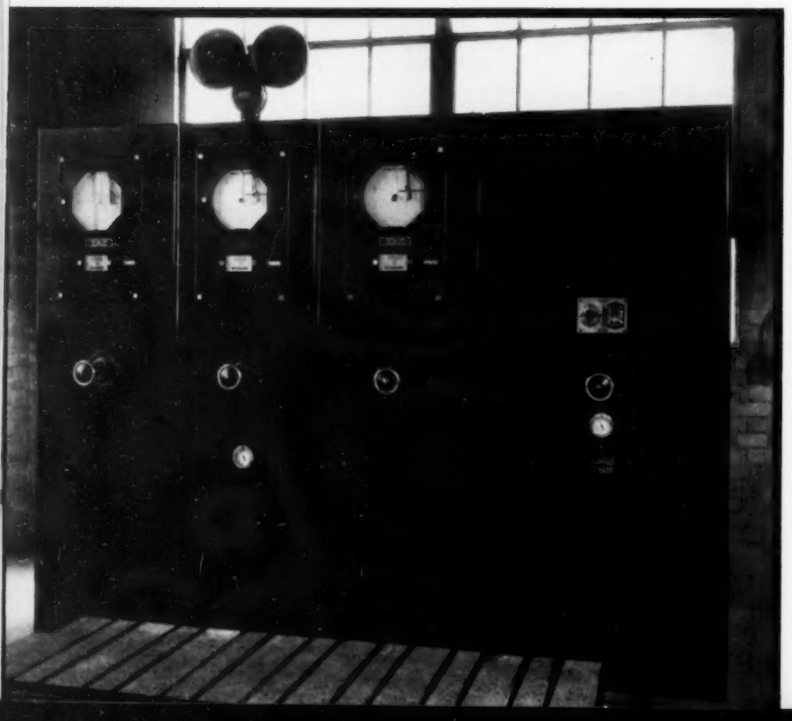


FIGURE 5—This equipment controls the mixing of coke oven gas and blast furnace gas in a plant of 3,250,000 cu. ft. per hr. capacity.

FIGURE 6—Gas flow, gas temperature and gas pressure are recorded on the coke oven gas, blast furnace gas and mixed gas.



in the inlet mains when the pressure in the inlet main drops below 12 in. of water. The other two are located one on each outlet. Both are operated from the piston height mechanism. At 825,000 cu. ft., or about 400,000 cu. ft. below the usual height of the piston, a siren sounds at the reversing room; heater, battery foreman and foreman give their attention to the situation, if they have not done so before and, if all other moves have failed, change the ovens to coke gas under-firing or put the reversing machines into neutral before the piston touches bottom. At 150,000 cu. ft. a butterfly valve in the 48 in. main to the booster station is automatically closed.

An instrument board is mounted in the by-product exhauster room to give the operators the necessary information in controlling the flow to the holder. Recording instruments measure gas flow, temperature and pressure. The selsyn indicator mentioned before shows the amount of gas in the holder. Abnormally high holder pressures, 14 in. of water or more, and abnormally low pressures, 10 in. or less, through an arrangement of mercoid switches, bells, and lights, signal a sticking piston or much more commonly, rapid piston travel.

For efficient precipitator operation and to avoid disturbing the blast furnace gas system generally, efforts are made to avoid excessively high or low flow.

COKE OVEN GAS

To produce the coke required for three furnaces operating at the rate indicated, 2,740 tons of coal must be carbonized per day. An average yield of 29,600,000 cu. ft. of gas is obtained, or 10,800 cu. ft. per ton of coal.

A typical analysis of this gas after it has been cooled and scrubbed to remove tar, ammonia, naphthalene and light oil and cleaned in electrical precipitators to remove tar fog, is shown in Table I. Hydrogen sulphide content is usually 100 to 120 grains per 100 cu. ft.

There are three tar precipitators of which two are operating at a time. Each has 60 tubes, 8 in. diameter by 9 ft. long. Unlike the blast furnace gas precipitators, these tubes are not washed by a film of water; instead, the fog particles are caught in a film of tar which flows down as it accumulates sufficiently.

A 36 in. main conducts the scrubbed gas away from the by-product plant. From this main there are outlets to the blast furnace gas enriching system, to the boiler house, to the coke ovens for underfiring, to the bleeder and to No. 2 booster station. An 8 in. relief valve set at 27 in. of water and a 12 in. valve set at 29 in. of water, release gas to the 20 in. bleeder stack. A regulator controls a motor operated butterfly valve in this main to maintain a minimum plant pressure of 16 in. Between this regulator and the booster station is a connection through which purchased coke oven gas is introduced to the system. An air operated controller shuts this gas off as the pressure exceeds 24 in. of water.

Besides the coke oven gas, another by-product fuel, coke breeze, is produced. After the requirements for bottom making at the soaking pits are met, 107 tons per day are available for firing boilers on special chain grate stokers.

GAS REQUIREMENTS

Blast furnace stoves are universally heated with blast furnace gas without standby fuel. It is usually possible to discontinue the heating of one stove at each furnace for some time, depending on the need for blast heat, if there is a shortage of gas. About 28 per cent of the gas produced is the stoves' requirement, although the stoves of "C" furnace with small checker openings, require only about 23 per cent. These requirements show considerable variation with blast temperature.

Blast furnace gas is especially well suited for the heating of coke ovens, where the temperature requirements are easily met with preheated gas and the combustion characteristics give the desired heat distribution throughout the length of the heating flues. It is enriched by the addition of coke oven gas to increase and control the Btu. value.

The enriching apparatus consists of two 8 in. pipes with closed ends, extending into the blast furnace gas main to form a cross. Coke oven gas is discharged into the blast furnace main through ½ in. holes drilled into these pipes so that the discharge is at right angles to the flow of blast furnace gas. A regulator valve adjusts for variations of coke gas pressure. A motor operated butterfly valve, remotely controlled from the reversing room at the ovens, regulates the flow. A selsyn indicator shows the position of this valve. A continuous recording calorimeter is the guide in making adjustments. Little trouble has been experienced in controlling to within 1 Btu. of the desired value.

The ovens may be heated with coke oven gas instead of blast furnace gas. A diluted coke oven gas of about 450 Btu. is more satisfactory than the 565 Btu. gas. Since the blast furnace gas main is at lower pressure than the coke oven gas main, a booster is necessary. This is a single-stage centrifugal blower which has a capacity of 2,050 cu. ft. per min. at 3,500 rpm. and will produce a pressure rise of 36 in. of water under these conditions. A flow controller holds the blast furnace gas at the required rate and records the volume used. Since the gas flow to the ovens is controlled, this approximates volumetric mixing and is fully satisfactory for the purpose. The capacity of the system is about 475,000 cu. ft. per hour when diluting to 450 Btu.

Uniformity of heating of coke ovens is essential to good operation. An uninterrupted supply of gas for their underfiring is required and the ovens are given preference. Change-overs are made as seldom as possible to avoid irregular heats.

Four of the five boilers are normally operated to generate the plant steam requirements which range from 215,000 to 240,000 lb. per hr. at 400 lb. per sq. in. and 700 degrees F. These boilers are rated at 75,000 lb. per hour. All five boilers are equipped to burn either blast furnace gas or coke oven gas. No. 1, 2 and 3 may be fired with oil, also, and No. 4 and 5 have grates for burning coke breeze. Oil is an emergency and stand-by fuel; breeze is both a regular and stand-by fuel.

An air operated control system coordinates the operation of all five boilers. A master control, sensitive to steam header pressure, transmits air loading pressures to all five boiler controls. At the boiler controls the air loading pressure operates to control the amount of gas to the burners. Separate air-gas ratio controllers are used for the combustion of coke oven gas and blast furnace gas.

The burning of coke breeze is the only combustion not automatically controlled. Rate of burning is changed by adjusting speed of grate travel and depth of fuel bed. Under-grate air pressure is adjusted manually from the boiler control panel.

Safety devices are provided on all boilers to shut off fuel in the event of failure of forced draft fan pressure and to shut down forced draft and fuel in the event of failure of induced draft. Time relays prevent the turning on of fuel after the draft fans have started until a set time has elapsed.

Boilers No. 4 and 5 are provided with an automatic spill for coke oven gas, by which, when the coke oven gas main pressure rises to 21 in. of water, a change from blast furnace to coke oven gas is started. At 25 in. pressure this change is complete and the blast furnace gas is replaced by an equivalent amount of coke oven gas.

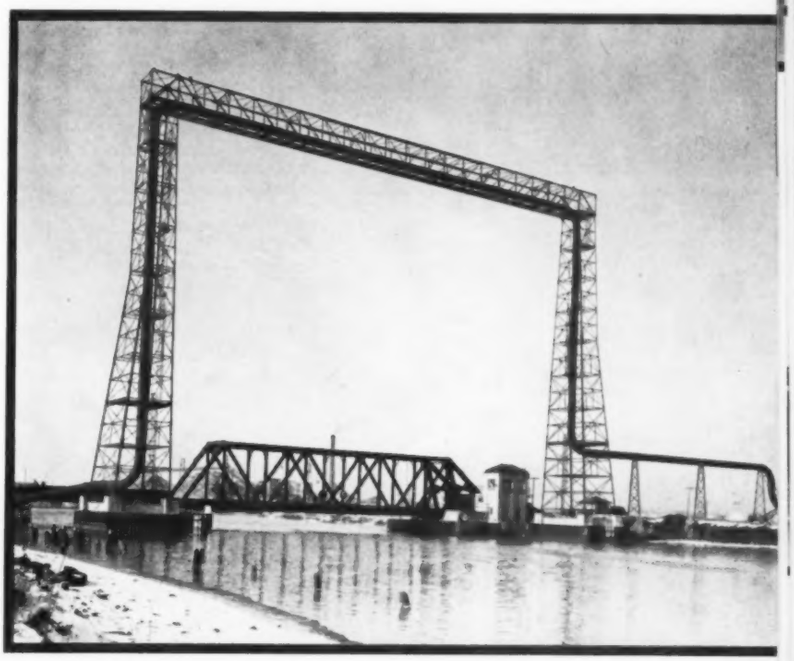


FIGURE 7—The 42 in. mixed gas main is carried on this overhead bridge over the Short Cut Canal.

BOOSTER STATIONS

Booster station No. 1 compresses the blast furnace gas consumed in the boilers of a neighboring central power station. The main, 48 in. diameter, crosses the River Rouge on an overhead bridge which has a clearance above the water of 150 ft. This bridge also supports the main which brings purchased coke oven gas to the plant. Two single-stage centrifugal blowers in this station have a capacity of 35,000 cu. ft. per min.

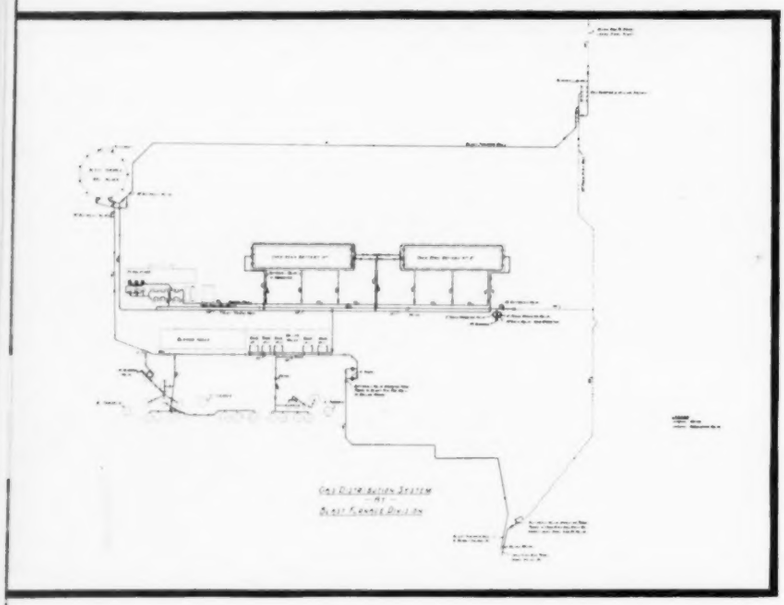


FIGURE 8—Diagram showing layout of coke oven gas and blast furnace gas systems at Hanna Furnace Division.

each at 1750 rpm. with 8 in. of water inlet pressure and 21 in. discharge pressure. They may be operated singly or in parallel.

In the discharge main is a butterfly valve operated by a pressure controller which begins to open with a blast furnace gas pressure of 17 in. in the boiler house and is open wide at 22 in. The purpose of this slowly operating regulator is to maintain a minimum pressure in the boiler house and holder inlet main without rapid variations of gas pressure at the central power station. The butterfly is adjusted to a minimum flow of about 300,000 cu. ft. per hr. with the blower stopped. If a lower flow is necessary, flow is stopped completely and the main is purged with inert gas before it is resumed.

FIGURE 9—View showing front of control and instrument board on slab heating furnaces of No. 2 hot strip mill.

The mixing of blast furnace gas and coke oven gas gives a fuel more satisfactory for some purposes, permits the development of more heat from gas than if coke oven gas were used alone and extends the field of usefulness of blast furnace gas. At booster station No. 2 the equipment for mixing and compressing these gases for the steel mill is located. The mixing is calorimetric, that is, to constant Btu. value; with this type of control and mixing of two gases of fairly constant composition, specific gravity, air requirements for combustion and flame characteristics of the mixed gas are also constant for all practical purposes. Usual mixing is accomplished with a Btu. variation of 5 Btu., plus or minus. Typical composition of this gas is shown in Table I.

Blast furnace and coke oven gas enter the mixing equipment in separate 48 in. mains. Each main has two butterfly valves, operated by automatic regulators of the oil jet type. The first butterfly valve in the coke oven gas main is operated by a ratio controller, regulator No. 1 in Figure 3, which is adjusted to give a different ratio of the constituent gases by a calorimixer, according to the Btu. variations of the mixed gas.

The ratio controller has two diaphragms which react to the differential pressures of two orifice meters measuring the constituent gases and move an oil jet pipe which sends oil pressure variations to the oil cylinder operating the butterfly. Ratio changes are made by changing the position of a fulcrum on the end of a "ratio slider," thus requiring a greater or lesser differential, that is, a greater or lesser gas flow to maintain a neutral position of the jet pipe. Ratio slider movements are made by an electric motor when contacts are made by the calorimixer. These movements are limited as to duration and frequency to prevent over-traveling and hunting.

Since meters with fixed orifices have no measurable differential at low flow and the ratio controller is dependent on the orifice differentials for its accuracy and sensitivity, in this installation variable orifices are used. These are the duplex butterfly valves operated by regulator No. 4 in Figure 3, to give a constant differential of one inch of water across the blast furnace gas butterfly. The duplex valve in the coke oven main travels with the blast furnace gas valve and its differential varies with different ratios of the two gases.

The first butterfly in the blast furnace gas main is operated by regulator No. 5 to give a pressure before the blast furnace gas duplex valve which is one inch of water less than the coke oven gas pressure entering the station, that is, before the butterfly operated by the ratio controller. This butterfly remains open on our present scale of operation but will operate with greater loads and lower coke oven gas pressures. It is also the emergency cut-off to prevent boosting straight blast furnace gas to the mill in the event of a coke oven gas failure.

If there is a blast furnace gas failure, which will occur if the holder piston drops to the point at which the butterfly valve in the main to the booster station is automatically closed, then the duplex valves will close because of no differential across the blast furnace valve and the coke oven gas is thus shut off. In the case of these failures and resultant closing of butterfly valves, there is sufficient gas passage to permit holding a slight positive pressure of about 0.1 lb. per sq. in. in the dis-

charge main and purging is unnecessary. At the same time, the mill gas system is not filled with a gas unsatisfactory for the burners. After the duplex valves, the gases mix as they enter the inlet main to the compressors.

There are three centrifugal compressors. They have three stages and a capacity of 27,000 cu. ft. per minute, when pumping gas of .604 specific gravity, with a discharge pressure 6 lb. per sq. in. and inlet pressure and temperature 8 in. water gauge and 80 degrees F., respectively. Each compressor is driven by a 1000 hp. induction motor, operating on a voltage of 4600, and at 3575 rpm., full load. The starters are reactor type and are interlocked to prevent starting with no oil pressure in the lubricating system and to prevent starting with a load on the compressor, that is, with an open discharge valve.

Load regulation is by means of movable vanes in the inlet or "power wheel" section of the machine. This arrangement gives lower power consumption, especially at low rates of operation, than other types of control for constant speed machines. Power required for pumping gas to the mill at an average pressure of 4 lb. per sq. in. when operating at 80 per cent of capacity, is about 420 kwh. per million cu. ft. Water is sprayed into the inlet of the machines for lubricating the vanes, cooling the machine and keeping the machine clean. Two regulators are used for the vane control. The inlet control, No. 3, operates to hold the pressure in the coke oven gas main before the booster station at 16 in. of water. If the discharge pressure builds up to 4.5 lb. per sq. in., the vane control is switched over to the discharge regulator, No. 2. This is accomplished by a solenoid three-way valve in the oil impulse line from the regulators to the vane control. Pressure operated mercoid switches energize the solenoid in the proper direction. When inlet control pressure conditions return, the solenoid valve is changed and regulator No. 3 again takes control. This inlet main control was installed to prevent bleeding of coke oven gas in a system which has no gas holder and comparatively little capacity. The discharge control prevents imposing unreasonably high pressure upon the mill system. Both regulators are well stabilized to prevent hunting.

Instruments have been installed to give the gas dispatcher at the station all information possible. Coke oven gas, blast furnace gas and mixed gas each have three-pen recorders for gas flow, gas temperature and gas pressure. A pressure recorder is connected into the inlet main of the compressors. An indicating flow meter measures the coke oven gas to the boiler house. The selsyn indicator mentioned previously shows the amount of blast furnace gas in the holder. Light signals show the position of the 8 in. bleeder valve, whether open or closed. A calorimeter records the Btu. of the mixed gas and supervises the calorimixer.

The sample line for the calorimeter and the calorimixer is a ¾ in. line from the discharge main to the inlet main and thus has a greater flow of gas than the requirements of 10 cu. ft. per hr. of the instruments. This is to bring Btu. variations to the instruments with the least lag. The sample line also has a water separator, since spray from the water to the compressors has not dropped out. Oxide catch boxes, to remove sulphur and prevent corrosion, are used. The problem of corrosion

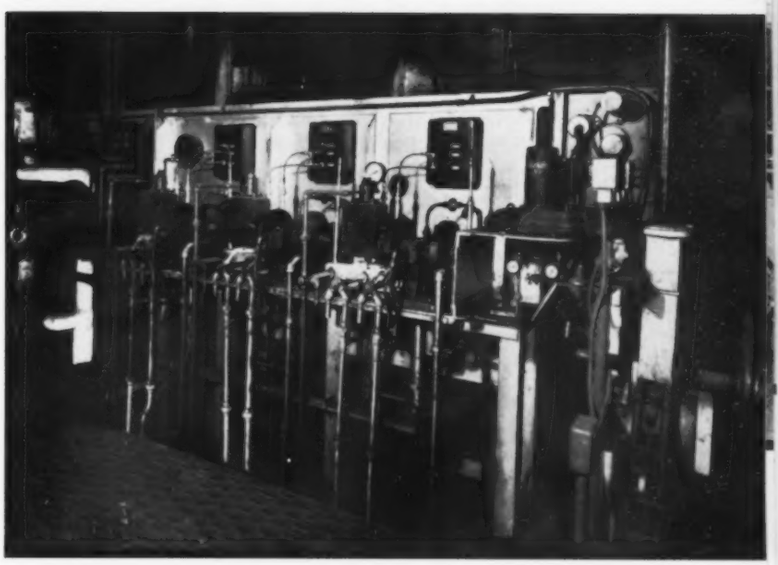


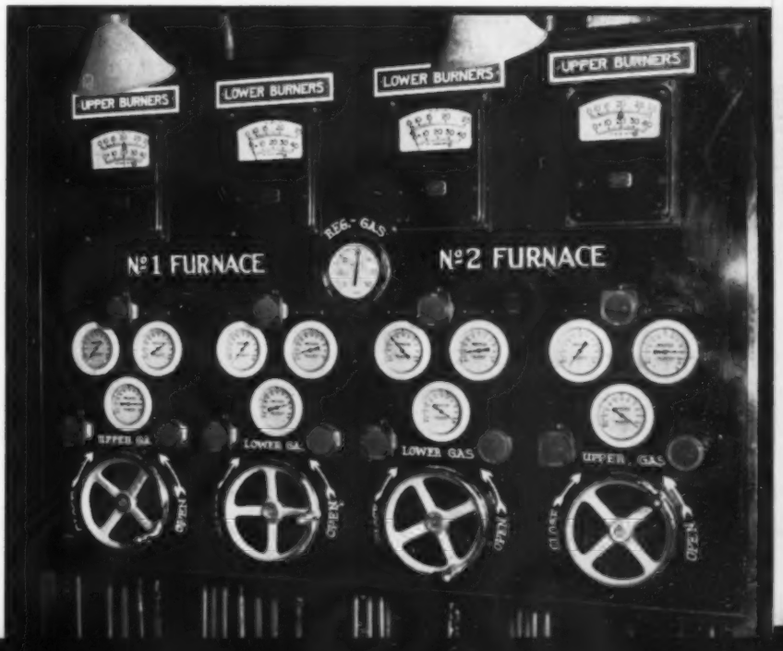
FIGURE 10—Rear view of board in Figure 9, showing control mechanism, gas regulator, and safety shut-off valve.

control in the calorimixer has not been fully solved yet.

The gas is conveyed to the mill in a 42 in. main 2.2 miles long. The pressure loss in this distance when carrying 2,400,000 cu. ft. per hr. averages 1.25 lb. per sq. in. An above ground section 0.4 miles long has expansion joints but the underground section has expansion couplings at intervals of about 40 ft. The underground portion is protected against corrosion by pitch and pitch saturated felt paper. There are 21 drip pots for the removal of condensate from the main. The first four are self draining; at pressures of 3 lb. per sq. in. or more, the drip water is forced out into a seal pot from which it flows to the sewer.

The main crosses the Short Cut Canal at the south

FIGURE 11—This panel board carries controls and instruments for the slab heating furnaces of No. 1 hot strip mill.



edge of Zug Island on another overhead bridge. Channel clearance of the bridge is 199 ft. and water clearance is 150 ft.

GAS DISPATCHING

At this point the mixed gas has been delivered to the mill but before its consumption there is discussed, some idea of the dispatching necessary to meet variations in supply and demand at the furnace division should be conveyed. The coke plant turn foreman has the responsibility of dispatching because he is best trained by experience, has the sources of necessary information at his command and is most free to move about in the plant. He must survey each situation and use his judgment. The supply of blast furnace gas is somewhat uncertain because of furnace shut downs and other variables in operation. A shut down is preceded by the blowing of a signal on the boiler house whistle on instructions from the furnace blower. Shortages from other causes are indicated by a dropping holder piston.

While each situation must be handled according to its own particular conditions, the turn foreman has the following to guide him:

1. The output of No. 1 booster station will be reduced within the limits of the butterfly valve; the blower may be shut down; if necessary, flow may be stopped completely.
2. If the shut down is of short duration, stove burners may be pulled. Blowers have standing instructions to do this for such shut downs which occur with little or no advance notice.
3. Coke breeze may be increased on boilers No. 4 and 5 and fuel oil may be used on the other boilers. Coke oven gas will be used ordinarily only as the mill load permits.
4. If possible, the mill load will not be disturbed.
5. Change over to coke oven gas for underfiring the ovens will be avoided. It is to be noted that such changeovers disturb the mill load considerably.
6. Good judgment must be exercised in using the contents of the holder. Like a good general in battle, the turn fóreman must recognize the time to throw in his reserves and then reform them at the first opportunity. It is important to note that with the rate of operation indicated in Table II, the holder will travel from 1,300,000 to 150,000 in 20 minutes if no gas is entering.

Table II shows four cases. The first, ABC, is normal operation. Case AB is an actual shut down of "C" furnace of 2½ hours duration which was anticipated and for which plans were made. Cases AC and BC are short shut downs in which stove burners are pulled. It is usually necessary to make some adjustments as soon as the trend of the holder can be detected.

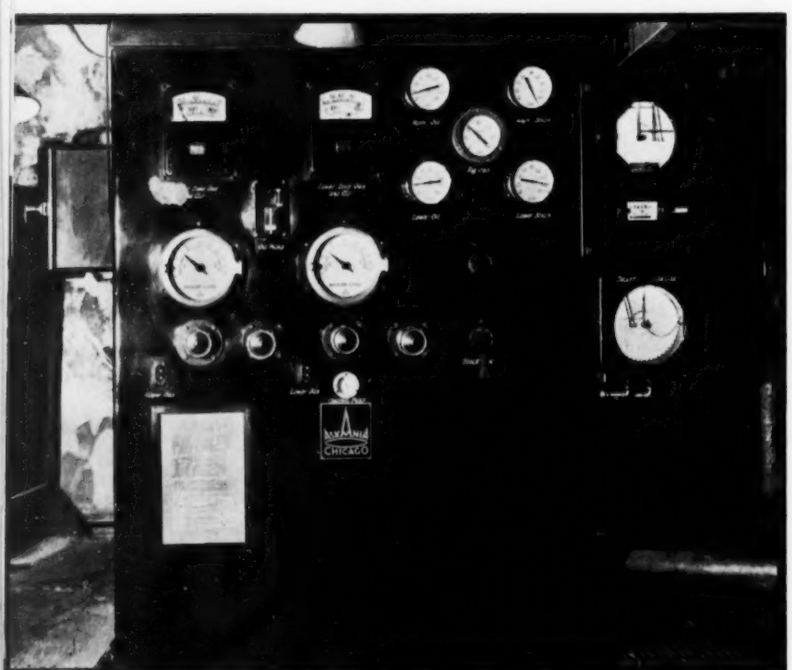
Since irregularities in charging the coke ovens effect gas production only gradually, the coke oven gas is more dependable than the blast furnace gas. The usual situation is an excess of coke oven gas due to decreased demand at the mill for which an outlet must be found. This is done automatically by the controls already described. The following occur with decreasing demand and increasing gas pressure:

At 16 in. pressure—Booster control
At 21 in. pressure—Boiler spill starts
At 24 in. pressure—Regulator starts closing on purchased gas
At 25 in. pressure—Maximum spill at boilers and purchased gas regulator closed
At 27 in. pressure—8 in. bleeder valve opens
At 29 in. pressure—12 in. bleeder valve opens

In addition to these automatic changes, coke breeze may be reduced on boilers No. 4 and 5 to make room for a greater spill and if there is an outlet for the displaced blast furnace gas, coke oven gas may be put on one or more of the other boilers.

The cooperation of all departments is required for the successful operation of the system.

FIGURE 12—The control board for No. 2 merchant mill furnaces includes gas and air flow meters, furnace pressure recorder, etc.



MIXED GAS DISTRIBUTION SYSTEM

A few years ago blast furnace gas was used entirely for heating blast furnace stoves; also in boiler plants for the generating of steam. Due to a low Btu. value of the gas itself, large volumes of this gas were accordingly burned ineffectively in single pass stoves, and in boilers using a roughly designed aspirating type gas burner.

By the improvements on present day blast furnace stoves, and boiler installations, which are automatically operated, the blast furnace produces a greater volume of gas for distribution.

For a number of years after by-product coke oven gas was introduced, it was used alone in the open hearth and heating furnaces, etc. Several years later an attempt was made to mix the low Btu. blast furnace gas with a correspondently higher Btu. by-product coke oven gas, which has proved to be very successful in the steel industry. The average Btu. of our mixed gas is 370 per cu. ft.

TABLE II

Fuel Production and Consumption

(Gas figures are thousands of cu. ft. per hr.)

Furnaces operating	A, B, C	A, B	A, C	B, C
Blast furnace gas production "A" furnace	3,278	3,278	3,278	....
Blast furnace gas production "B" furnace	2,817	2,817	....	2,817
Blast furnace gas production "C" furnace	5,268	....	5,268	5,268
Total	11,362	6,095	8,546	8,085
Blast furnace gas to "A" furnace stoves	1,125	1,125	750	....
Blast furnace gas to "B" furnace stoves	880	880	....	520
Blast furnace gas to "C" furnace stoves	1,212	....	606	606
Blast furnace gas to power plant	2,040	630	1,293	1,104
Blast furnace gas to coke ovens	2,357	2,357	2,357	2,357
Blast furnace gas to mill	968	968	968	968
Blast furnace gas to boiler house	2,780	135	2,572	2,460
Coke breeze consumption, tons per hr.	3.75	6.35	3.75	3.75
Oil consumption, gal. per hr.	.....	375	....	....
Plant steam load, thousand lb. per hr.	225	188	212	205
Coke oven gas produced, 565 Btu.	1,233	1,233	1,233	1,233
Coke oven gas to coke ovens	41	41	41	41
Coke oven gas bled	....	....	....	....
Coke oven gas to mill, 565 Btu.	1,142	1,142	1,142	1,142
Coke oven gas to boiler house	50	50	50	50
Coke oven gas purchased, to mill, 525 Btu.	300	300	300	300
Mixed gas to mill	2,410	2,410	2,410	2,410

The average daily amount of mixed gas used in the steel plant is 60,000,000 cu. ft. which is dispatched from blast furnace plant some 2¼ miles distant.

The mixed gas distribution system is laid out in a loop design, operating at approximately 35 in. of water pressure. The loop system practically eliminates pressure drop, and facilities for future expansion are afforded. The loop or belt system is very flexible, in that the gas piping has been designed to supply sources of demand, by dispatching the gas in more than one direction.

It can be observed from flow diagram that the position and location of header valves, allow various routes for dispatching of gas in the possible event of isolating certain sections of this system for inspection and maintenance purposes.

It is necessary in controlling and maintaining gas line pressure to have a gas dispatcher in constant connection with the furnace division dispatcher 24 hr. per day, to hold this line pressure of approximately 35 in. water.

We do not employ the use of a gas holder in the mixed gas system at the steel plant, therefore any excess gas is burned in the open hearth furnaces. Each open hearth furnace will burn 100,000 cu. ft. per hr. together with a corresponding cut in oil, to maintain good furnace conditions. Due to mill operation, or a change in gas flow from blast furnace we sometimes find it necessary to change from gas to oil, in order to maintain the gas line pressure. This change is made through the use of a combination gas-oil burner which is employed on all heating furnaces.

In the open hearth several types of gas burners were originally employed to burn mixed gas in the furnaces. Mixed gas was first used at the open hearth in October, 1938, and at present time an end combustion type of gas-oil burner is being used successfully. The burner is so designed that when burning both gas and oil, the oil is introduced above the gas flame which naturally tends to keep the flame from roof impingement. In some of our open hearth furnaces, roof temperature controls have been installed, which greatly increase the life of the furnace roof.

The mixed gas has entirely replaced producer gas which was originally used on all soaking pit furnaces. The gas is introduced through a 4 in. burner pipe to regenerative checkers. A marked economy and a very definite increase in efficiency of operation has been achieved.

The use of mixed gas at slab heating and billet furnaces has been highly successful, due to better measuring devices for gas-air ratio control. It is much easier to maintain a balanced draft on the furnace hearth due to constant gas pressure, when other types of heavy fuels are more apt to be intermittent.

Furnaces are equipped with a combination type gas-oil burner. The rate of firing, or fuel input is directly under the supervision of the heater who merely changes the fuel valve setting to each zone, and the automatic control equipment proportions the air in the new firing ratio. The fuel-air ratio is automatically maintained in each zone of the furnace, throughout the operating range, by use of gas metering regulators which function from pressure drop across the orifices installed in gas supply lines.

These regulators being of the sender type, generate

(*Please turn to page 38*)

FIGURE 13—The furnace on No. 1 merchant mill is provided with a panel carrying instruments and controls for burning either mixed gas or oil.

ELECTRICAL EQUIPMENT

... for Strip Processing Lines ...

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▲ AS we look back on the activities of the steel industry during the past decade, we realize that it has been a period when the industry was devoting a major part of its attention to the improvement of its equipment for producing flat rolled products. Each year has seen the addition of new continuous hot strip mills along with the necessary capacity in continuous cold rolling mills for the production of sheets and tinplate.

With the installation of each new mill, new developments have been included to not only produce a better quality of product but to produce it at a higher speed. Speeds of 2000 ft. per min. and above are accepted as normal for hot strip mills and this speed is being exceeded on the five-stand continuous cold mills for the production of tinplate.

The development of the continuous hot and cold strip mills has created a need for new methods in preparing the steel for rolling in the mills and in shearing, trimming, slitting and applying coating after rolling to meet any given specification. The various machines used for any certain process are mounted in tandem so that the steel travels from one machine to the next and the combination of the machines has become known as a continuous processing line. Some of these lines were unknown before the development of the continuous hot and cold strip mills and others have been changed and improved to meet the new conditions.

FIGURE 1—The modern continuous strip pickler calls for both individual and simultaneous control of motors and groups of motors.

The subject of processing lines is very broad and it is difficult to cover it properly in a paper of this type. Any one of the processes offers sufficient material for a fairly long discussion and so it is necessary to cover the general considerations of these lines only and avoid any attempt of detailed description of any one line. There are five principal types of processing lines which we think of when referring to hot and cold strip mills. The first process is the continuous pickling line which is used to remove the scale from the coils and hot rolled strip produced in the hot strip mill. This processing operation may be considered the connecting link between the hot and cold strip mill as the coils go directly to the tandem cold mill from the pickling line. Even though the pickling lines have been considerably increased in speed, 250 ft. per min. represents a fairly high speed for this operation and so it is still slow compared with the delivery speed of the hot strip mill. As a result, it is practically always necessary to have two and sometimes three pickling lines for each hot strip mill.

The next major processing line is the cleaning line. The function of this line is to remove the oil that is used in the cold rolling of the steel and which must be removed before annealing. Here the lines have been developed to a point where their delivery speed is approximately equal to the speed of the cold strip mill but it is normal practice to have two lines for each cold strip mill. After annealing, the steel is usually put through the skin pass or temper pass mills to give it its proper physical characteristic. If the steel is to be shipped in coil form a third group of processing lines either for side trimming and recoiling or slitting and recoiling is provided. The function of this line is to produce coils of an exact width and with good edges.

A large percentage of the steel is still shipped in sheet form and a group of lines known as shearing lines have been developed to cut the coils into exact lengths and

several forms of these lines are in use depending on the width and thickness being handled.

The last main group of processing lines consists of lines to apply a metallic coating to sheet steel. These lines are known as galvanizing or tinning lines. This process is older than the continuous strip mill and the galvanizing and tinning lines are still mainly designed to handle steel in sheet form rather than in coils. However, a large amount of development work is now being done to develop continuous processes using the steel in strip rather than sheet form. The main problem in the development of these processes is in the application of the coating rather than any handling problem in carrying the sheet through the processing line.

While there are other types of processing lines that are used for certain special conditions, and new types of processing lines to provide for new methods are being developed, the ones mentioned above are the basic production units and are representative of this type of equipment.

So far as the electrical equipment is concerned the simplest type of line is one in which all of the motors maintain approximately the same relative speeds at all times and when the steel is comparatively thick and moving at a relatively slow speed. A pickling line or plate shearing line falls within this classification. The electrical equipment becomes more elaborate as the speeds of the steel increase and also where the relative speeds of the motors change. Cleaning lines and slitting lines are of this type as they are equipped with reels which wind up the strip under control of constant current regulators and the relative speed of the reel motor to the rest of the motors is constantly changing over a range in excess of 2 to 1.

The continuous strip pickler as now developed is a typical example of a line that has developed so that a large number of motors can be either individually or simultaneously controlled and the entire group of motors so interlocked to give the most efficient operation. A typical modern installation is shown in Figure 1.

Some of the original pickle line installations consisted of only a few sets of pinch rolls, upcut shears, stitcher and a recoiler. The modern lines now contain several

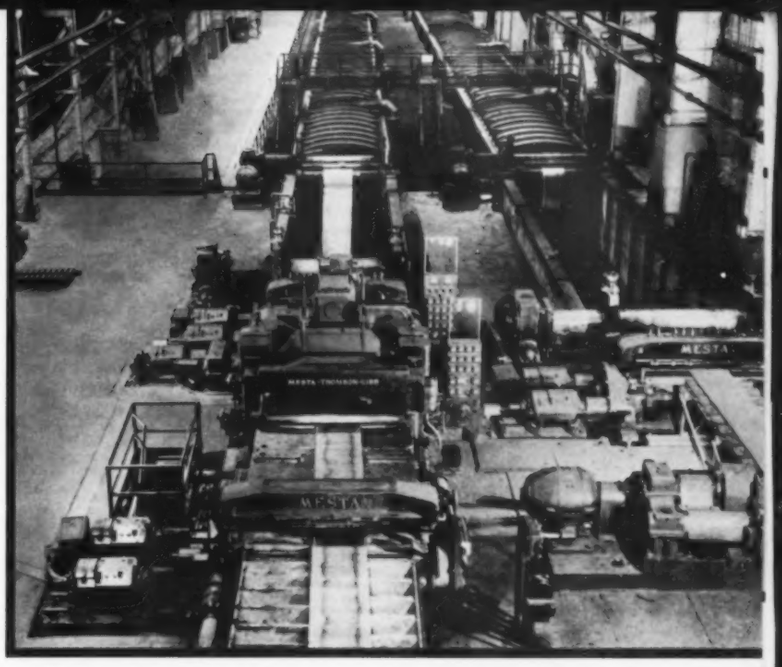
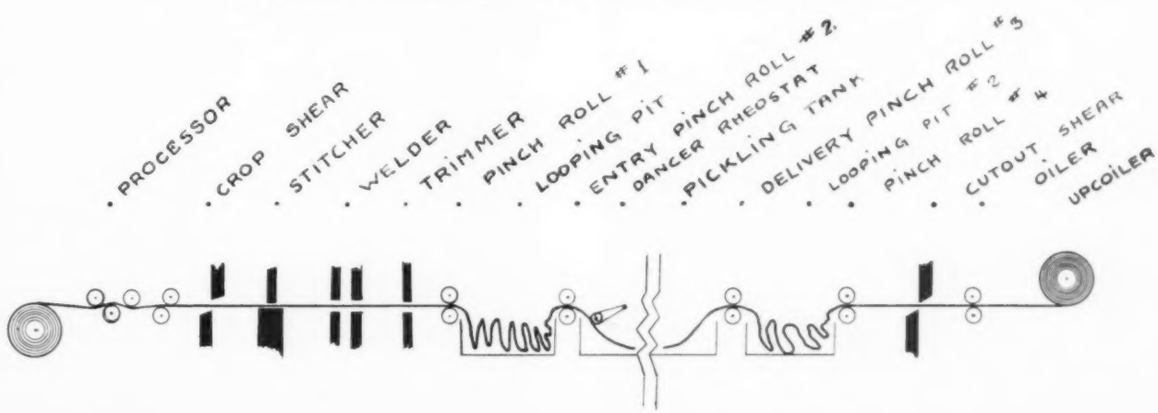


FIGURE 2—The modern pickling line usually includes a flash butt welder in addition to the mechanical stitcher.

other auxiliary devices. For instance, the ordinary coil box of the early installation has now been replaced by a processing machine that not only is used to unwind the coil and feed it into the pit in front of the pickling tanks but also actually works the metal by sending it through a series of rolls to help in the removal of the scale. Besides the main drive of the processor, there are usually three or four other small auxiliary drive motors used in connection with the handling of the coil.

Where the initial lines provided only for a stitcher to connect the coil ends together, the modern pickle line not only includes the squaring shear and stitcher but also includes a rather elaborate flash welder that can be used to weld the two coil ends together, then trim off the surplus metal and do a job of such quality that the weld itself can be rolled in the cold mill. A typical welder is shown in Figure 2. This feature has nothing to do with the pickling process but does serve as a

FIGURE 3—Schematic diagram of layout of continuous strip pickling line.



means of getting larger coils for the cold reduction mills when conditions are such that the desired size coil cannot be rolled on the hot strip mill. This is an example of an addition to a processing line of an auxiliary operation that has nothing to do with the process but is located here since it is a convenient point at which to perform it.

The standard pickle line, of course, has a looping pit in front of the main pickling tanks to allow sufficient accumulation of strip so that the steel can flow through the pickle line continuously while the ends of the strip are being welded together. The arrangement of having both an entry and delivery pinch roll is still used on all pickle lines similar to original installations, although the dancer roll mechanism has been improved so that much of the maintenance of the early installations has been eliminated.

On the delivery end, most of the new installations also include a looping pit to allow for an accumulation of the steel while the stitch is being cut out and while a new piece is being started into the recoiler. However, the looping pit does not have to be so large as the amount of time required to change the coils is much shorter than that required to weld the ends of the strip together. Most of the pickle lines also include some sort of an oiling device on the delivery end so that the pickled coil is not so apt to rust. A schematic layout of complete line is shown in Figure 3.

On a line of this type as many as 5 control desks are used, one at the uncoiler, one at the stitcher, one at the welder, and the main operator's control desk for the entry end at the pinch roll in front of the looping pit.

The complete control for the pickling tanks and for the delivery end is usually concentrated in one large control desk at the delivery end. From these control desks the various motors can be manipulated to control the flow of strip through the line. The line itself is divided into three main speed control groups with suitable duplex rheostats to adjust the speed of the motors simultaneously. The first section consists of the uncoiler, and the pinch rolls ahead of the looping pit. The second section consists of the entry and delivery pinch rolls that carry the strip through the pickling tanks and the two pinch rolls are controlled as a unit with individual inching switches from the desk at the delivery end of the line. The third section consists of the pinch roll and upcoiler at the delivery end. These three groups are all started and stopped independent of the others and no accurate speed matching between the various sections is necessary since there is usually an accumulation of steel in the looping pit. Suitable signaling and interlocking is provided between the various groups, however. For instance, the operator at the entry end can stop the entry and delivery pinch roll motors and the delivery end if all of the steel is taken out of the looping pit in front of the pickler. However, he is unable to restart these two sections since that can be done only at the delivery end. The operator has a switch that stops the line and prevents it from being restarted until he throws the switch back in the other direction which gives a signal to the delivery end that it is all right to start. These main details and many others are all included in a successful pickler operation today and every installation as it is made is changed from previous installations to meet the particular conditions of the mill in which it is installed.

There is one point that should be emphasized in regard to continuous pickle lines and for all processing lines where 4 to 1 speed range motors and rheostatic control are used. It is the usual practice to say that a motor rated from 400 to 1600 rpm. by field control will give a strip speed of from say 60 to 240 ft. per min. While such is undoubtedly the case for a given set of gearing, it must be kept in mind that some leeway must be made for the fact that the two motors on the entry

FIGURE 4—View of entry end of a representative installation of a cleaning line.

FIGURE 5—The delivery end of the cleaning line consists of a pair of pinch rolls, a three-roll drag mechanism, and the rewinding reel.

and delivery pinch rolls, for instance, have to operate in synchronism with each other and that this is done by means of a dancer roll working from the loop in the tank.

Experience has indicated that it is necessary to have from 8 to 10 per cent regulation, plus or minus, in this dancer roll rheostat to effectively control the strip. Therefore, the motor controlling the delivery pinch roll must have a permanent resistance connected in series with its field to raise its speed 8 to 10 per cent above the base speed. Then by the position of the dancer rheostat, it can control the speed of the entry pinch roll motor a given percentage above or below this speed. This means that if the pickle line had been geared for a delivery speed of 60 ft. per min. with the motor running at 400 rpm. that the minimum speed at which it could be reduced would be 10 per cent above 60 or 66 ft. per min. If this were the only factor involved, it would probably never be noticed that the minimum speed of the line could not be obtained. However, a large number of steel mills have a supply voltage of 250 volts instead of 230 volts which accounts for approximately another 10 per cent increase in speed above the 60 ft. per min. Also the pinch roll motors are usually running at a very light load at the low speeds since it is practically a constant torque load and the base speed of 400 rpm. can be obtained only at full load and since the motors have some regulation, this again accounts for an increase in speed. With all these factors combined, it is easily possible that a line originally intended for a minimum speed of 60 ft. per min. will not run at speeds less than 70 to 75 ft. per min. in actual practice.

In the past this usually has been of no importance to the operating people as most pickle lines were installed for a certain speed range and then operated practically under all conditions at about the maximum speed that it would run. However, as the operating speed range has been increased on pickle lines, there are some evidences that conditions may arise where the operator will need the lower pickling speed to remove all the scale.

This particular point has been mentioned in connection with pickling lines but it is a fundamental consideration for all lines operating in tandem and should be kept in mind. In other words, if a group of motors are to operate in tandem and have a 4 to 1 range in speed, it is an operating condition that makes it impossible to run the motors at this base speed and to obtain that 4 to 1 range in speed in the delivery speed of the metal unless the motors are run at above their rated speed.

Until recently, all pickling lines have been using rheostatic control but at present a line is being installed using variable voltage control. There may be several reasons for considering this step, but I believe that one of the most important is the ability to get a wider speed range and better control of the motors during the threading of the rear and front end of the coils through the cropping shear, slitter and particularly the welder. This part of the line is geared as high as 400 ft. per min. and in order to obtain threading speeds lower than 100 ft. per min. with rheostatic control armature shunt points must be used. It is evident that some difficulty might be expected in attempting to inch a 100 to 125 hp. motor and accurately spot the end of the strip in

FIGURE 6—At the delivery end of the cleaning line, the steel runs in a loop between pinch rolls and drag, under control of a vernier rheostat.

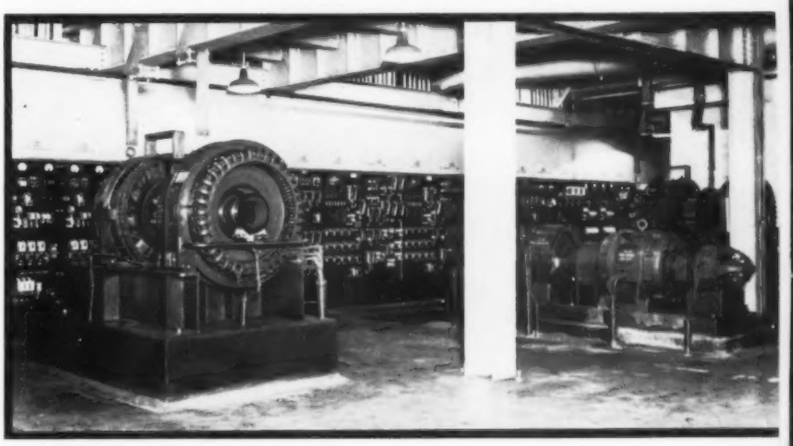
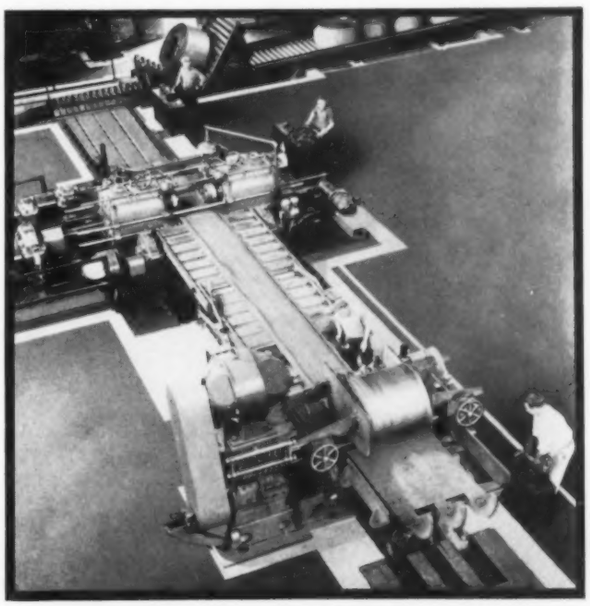


FIGURE 7—View of electrical equipment used in connection with electrolytic cleaning lines.

FIGURE 8—This processing line is used to trim the edges of the coil and rewind it into coil form.



the welder with rheostatic control. The problem is certainly much simpler with variable voltage control when inching speed as low as 20 ft. per min. can be obtained. Experience with this initial installation will influence the selection of electrical equipment on future pickling lines.

This also brings out another point which should be remembered in connection with processing lines. There is quite often a request for more than 4 to 1 range by means of field control. If it is attempted to obtain more than 4 to 1 range by field control on a d-c. motor, the regulation becomes very poor and it is very hard to operate the motors in tandem. It is therefore standard practice to recommend that if a speed range greater than 4 to 1 is required, that the speed range should be obtained by means other than rheostatic shunt field control of d-c. motors.

With this brief discussion on pickling lines, we will move on to the next typical processing line called a cleaning line. A representative installation of the entry end is shown in Figure 4. This view shows the feed reel, welder, and washer. The only electrical equipment normally used on the feed reel consists of the necessary motors and control to manipulate the clamping and hoisting mechanism to properly place the coil in the coil box.

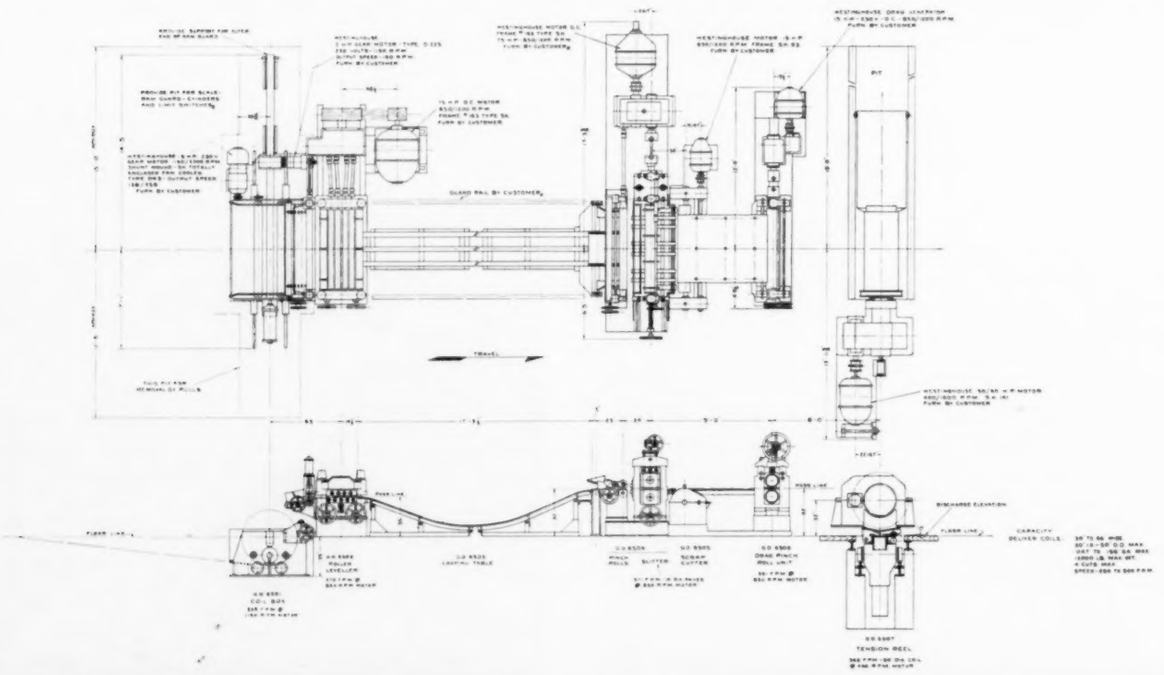
The welder is of either the spot or seam type and is simply used to weld the two coils together to avoid threading the line for each new coil. None of the motors on the entry end of the line are synchronized with the motors on the delivery end except in case a drag generator is used on the feed reel. Most of the feed reels are equipped with friction brakes to put some tension in the strip as it flows through the cleaning solution, but if it is desired to avoid the maintenance of these friction drags, an electric drag generator can be supplied in which case it receives power or supplies power, as the case may be, to the variable voltage system which supplies power to the motors on the front end of the cleaning line.

The delivery end of the cleaning line is shown in Figure 5. Here the units consist of a pair of pinch rolls that are used to pull the strip through the cleaning solution, a three-roll drag to provide a drag mechanism for the reel motor to pull against and the third unit consists of the reel itself. You can see that the strip runs in a loop between the pinch roll and the drag generator. This loop is necessary as it makes it much easier to guide the strip onto the reel and get the edges of the coil smooth when the reel is pulling against the drag device.

As we have previously indicated, the problem of synchronization of the various motors on a pickle line is fairly easy because of the relatively slow delivery speeds of the metal and the fact that the strip itself is fairly thick and not easily broken. However, when it comes to the control of cleaning lines where the steel is only a few thousandths thick and where it is being handled at speeds up to 1500 ft. per min., the problem of synchronization and of acceleration and deceleration of the motors becomes very important and more difficult to control.

On the early installations of cleaning lines, the speeds were much slower, sometimes not over 500 ft. per min. and under such conditions it was possible to obtain fairly satisfactory operation with rheostatic control. It was also possible to obtain sufficient tension by means of friction drags and wipers to obtain a sufficiently tight

FIGURE 9—Diagram of slitting line consisting of coil box, leveler, looping table, pinch rolls, slitter, scrap cutter and tension reel.



coil on the reel. However, as these lines have been increased in speed practically all installations are now being made with variable voltage control and are using drag generators to maintain tension on the strip being coiled. The very fact that the reel motor is rated at 75 hp. on the modern high speed cleaning lines indicates that a great deal of maintenance would be required of a mechanical drag to maintain sufficient back tension on the strip. Therefore, on many of these lines a 3 roll drag device has been developed to which is connected a drag generator to produce the necessary back tension. This device not only reduces maintenance but gives a more uniform tension and a more stable operating line.

A cleaning line is a good example of a constant torque application since about the only work being done is the

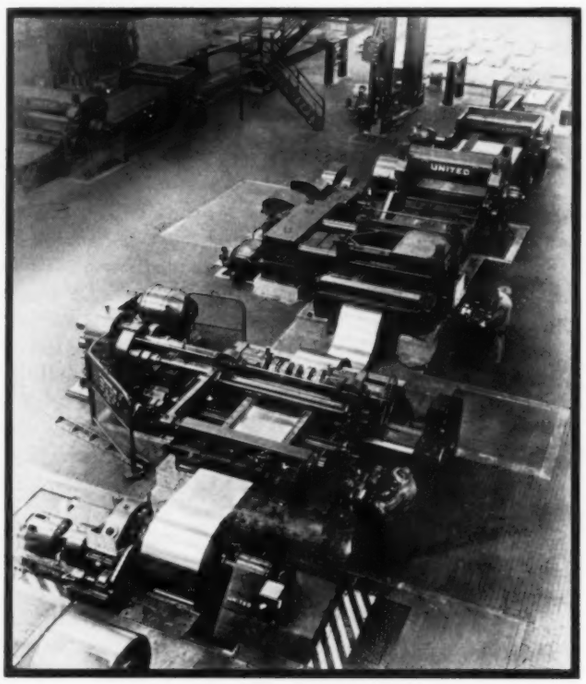


FIGURE 11—This sheet shearing line consists of an uncoiler, a side trimmer, and a combination leveler and flying shear.

work required to pull the strip through the line. Therefore, the hp. requirement of the motors is almost directly proportional to the speed of the steel which is an ideal condition for variable voltage motors and control. This feature will be described in detail later in the paper.

Another thing that makes the use of variable voltage control very desirable on a cleaning line is that it makes it possible to adjust the delivery speed of the mill by means of generator voltage control and then leave the shunt field motor control on the reel motor to compensate for the changing diameter of the reel.

A line such as we are discussing on which a reel is used and where the speed of the motor of the reel has to change relative to the rest of the motors on the line due to the changing diameter of the building up coil represents a more difficult problem so far as control is

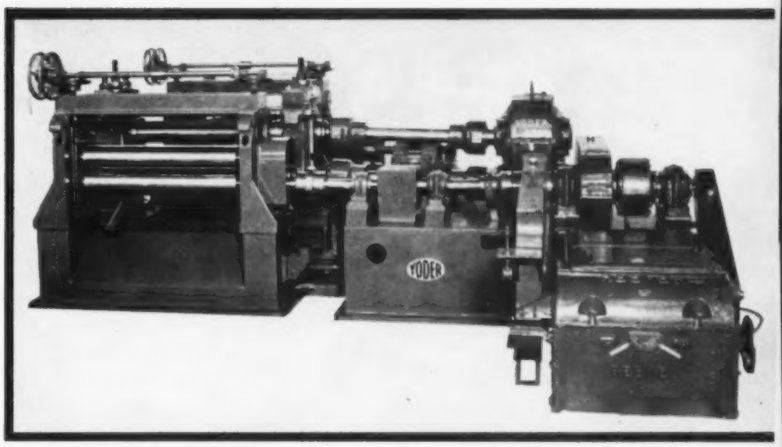


FIGURE 10—In this design, the slitter and a pinch roll are geared together through a variable ratio transmission and driven by a single motor.

concerned since the relative inertia of the reel motor to the other motors is constantly changing and the torque that the motor develops for a given current is constantly changing relative to the other motors.

Since most cleaning lines are arranged for a coil build-up of 2 to 1 or more, it is evident that it would be impossible to obtain much in the way of speed range of a cleaning line if only rheostatic control was used since the total range over which the reel motor can operate is only 4 to 1 and if 2 to 1 or more of the range is taken up with coil build-up, only a small amount of speed range is available for adjusting the delivery speed of the steel in feet per minute. Therefore, on a cleaning line of this type, it is recommended that all of the speed range be obtained by means of voltage control and that the pinch roll motor and the drag generator voltage motor only have a small amount of field control, say

FIGURE 12—Variable voltage control is widely used on tinplate shearing lines, where the material is thin and speeds are high.

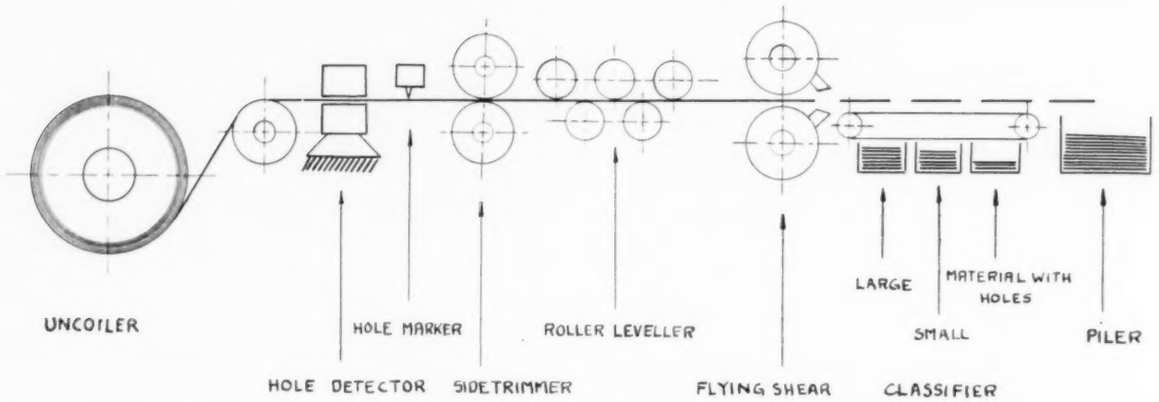


FIGURE 13—Schematic diagram of layout of tinplate shearing line in which a pinhole detector is incorporated.

20 or 30 per cent, in order to give a small amount of relative adjustment to the various motors in order to control the loop. By referring to Figure 6 you will note that the steel runs in a loop between the delivery pinch roll and the drag generator. Experience has indicated that even at speeds up around or in excess of 1000 ft. per min. that the loop can be easily controlled by means of a vernier rheostat on the pinch roll motor. Numerous attempts have been made to automatically control this loop by means of rider rolls, limit switches, and other devices but all of them have certain operating disadvantages. The worst feature is that it is extremely difficult to operate a limit switch or rider device from the steel itself since it is so light and is apt to become tangled or tear if a device of this type is used. In addition, many operating people claim that any device such as this has a tendency to mark the strip. However, by means of variable voltage control and by using an electric drag to maintain the back tension on the reel, the system becomes very stable and only a minor amount of manipulation is required to maintain a satisfactory loop.

The electrical equipment shown in Figure 7 indicates that quite a large amount of electrical equipment is required for one of these cleaning lines. In addition to all of the magnetic control equipment required for the variable voltage control of the various motors, there are also a large number of a-c. motors for which suitable control equipment must be provided. These a-c. motors drive scrubber brushes, pumps, and other auxiliary motors having to do with the cleaning process but which are not directly involved in conveying the strip through the cleaning line. In addition to the above, a high current low voltage motor-generator set is required in connection with the cleaning process which circulates d-c. current through the cleaning fluid.

The slitting lines are fundamentally very little different from cleaning lines in that there is always a tension reel involved for which a considerable portion of the shunt field range of the motor must be used to compensate for the build-up. However, since the speeds of the slitting lines have been greatly increased within the last few years, it is now rather general practice to use variable voltage control. Speeds are usually around 500 ft. per min. and since a strip may be cut into as many as eight separate strips, the power required for the slitter is usually rather large. There is one point in regard to slitting of steel which has always aroused the writer's curiosity and on which I can obtain very little definite information. That is, the relative advantages of power slitting and pull slitting. On lines that we are supplying at the present time, it usually results in that we find we have to arrange the control so that no power at all is applied to the slitter for some conditions operating as a straight pull slitter and on other occasions the statement is made that power must be applied to the slitter and under such conditions the slitter operates as a combination pull and power slitter since in practically every case tension is maintained between the slitter and the reel. Therefore, some power is being put into the slitter knives and at the same time tension is being maintained which tends to pull it through the slitter.

In some cases it is desirable to simply trim the edges off of the steel and no slitting is required. In this case the line is essentially duplicate of a slitting line except that the problem of handling several small coils on one reel is naturally more difficult than the handling of a single larger coil. A photograph of a typical recoiling line is shown in Figure 8.

A typical slitter line as indicated in Figure 9 consists of first of all, a coil box which may or may not have a motor drive and in some cases actually is equipped with a drag generator to maintain back tension. The next unit is usually a leveler and from the leveler the steel goes to the slitter. In practically every case a loop is maintained between the leveler and the slitter. From the slitter the steel goes on to the tension roll and under some conditions a mechanical friction drag is placed between the two and in other cases a pinch roll is used which can have its field control manipulated so that it serves as a drag generator to give back tension on the reel and then allows the loop to form between the pinch roll and the slitter so that all of the slitting can be done by power input to the slitter knives. On the

other hand, the pinch roll can be manipulated to run at such a speed that it tends to pull the strip through the slitter and thus produces pull slitting.

Another arrangement consists of the slitter and a pinch roll geared together through a variable ratio transmission and driven by a single motor. The variable ratio transmission is used to compensate for the changing diameter of the slitter knives as they wear down with use and regrinding. Such a drive is shown in Figure 10.

One point in connection with slitting lines which has caused considerable discussion is the correct type of drive for the scrap chopper which is used to cut the small piece trimmed off of the edge into short lengths to make it easier to handle. On various slitting lines, the scrap chopper has been driven by a constant speed a-c. gearmotor, an adjustable speed d-c. motor with power supplied from the 230 volt bus, and even in some cases the slitter has been connected on to the variable voltage bus.

If a constant speed a-c. motor is used, the length of the piece of scrap varies in inverse proportion to the speed of the line. In other words, when the line is running at minimum speed, the scrap is cut into short lengths and with the line running at its maximum speed, the pieces are proportionately longer. When an adjustable speed d-c. motor is used, the speed of the scrap cutter motor can be varied in approximate proportion to the speed of the line so that the length of scrap cut is practically constant regardless of the speed of the line.

When a motor for the scrap cutter is applied on to the variable voltage bus, the speed of the scrap cutter also varies in proportion to the speed of the line and gives a constant length of cut scrap. However, experience has indicated that it is not wise to start and stop the scrap cutter as the line is started and stopped due to the fact that the scrap cutter may stop just at the point where the blades are ready to make a cut and will jam up against a piece of scrap. Then when an attempt is made to restart the line, the scrap cutter will become jammed and the motor will become stalled, and the overloads will trip the motor off the line. For this reason it is recommended that if the scrap cutter is put on the variable voltage bus that the control be so arranged that the scrap runner run continuously down at the low voltage of the generator so that there is no possibility of this stalled condition appearing.

The next major type of processing line is the shearing line. They are fundamentally more simple than the cleaning and slitting lines in that no tension reel is involved since the coil of strip is being cut into definite lengths. The sheet shearing line as shown in Figure 11 consists of an uncoiler which may have an a-c. motor for coil manipulation or in other cases may have a d-c. motor which can serve for starting the coil through the line and can also be used as a drag generator to produce back tension. The next unit in the line is the side trimmer used to trim the strip to a definite width, and then the combination leveler and flying shear used to cut the strip in definite lengths. In practically all cases the line runs with a loop between the slitter and the flying shear. The final item consists of a conveyor and piler to pile the sheared strip. Most shearing lines used for handling the heavier strip use rheostatic control with the speed range obtained by adjusting the fields of the various d-c. motors. Here the strip is readily handled and the speeds are sufficiently slow to give satisfactory operation with rheostatic control, although in a few cases variable voltage equipment has been used. A typical tinplate shearing line is shown in Figure 12. On the tinplate shearing lines the steel is thin and the speeds usually higher so that variable voltage control is quite widely used. These lines, as indicated above, are somewhat simpler than the slitting and cleaning lines and there are no special problems so far as the control manufacturers are concerned that are especially difficult to solve.

There has been one interesting development recently made in connection with tinplate shearing lines that is rapidly becoming universal. Although no one is especially proud of the fact or particularly wants to talk about it, the fact remains that in the modern method of rolling tinplate, small pinholes seem to frequently develop in the strip. It is very important that these pinholes be detected before the strip is tinned and the shearing line appears to be the logical point at which to find and discard the sheets containing them. Since quite a few shearing lines are equipped with classifiers that automatically discard heavy and light sheets, it is

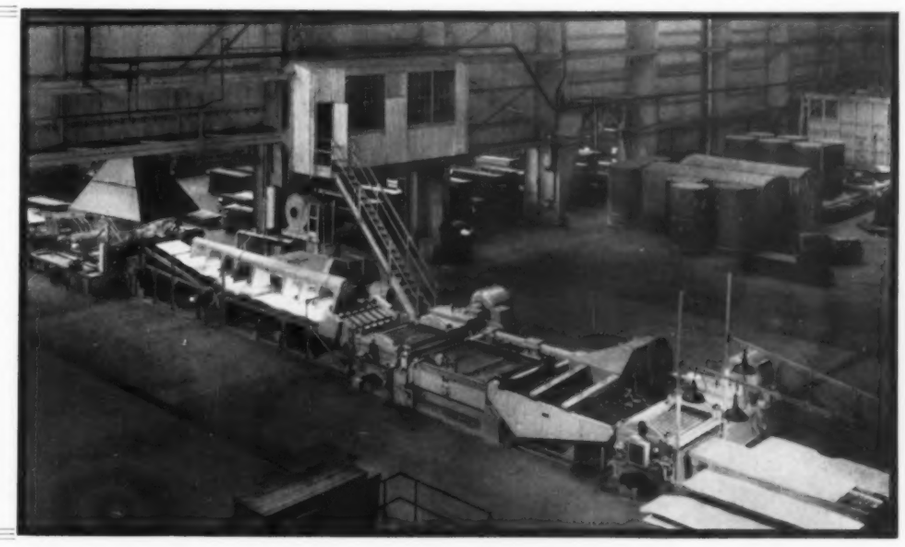
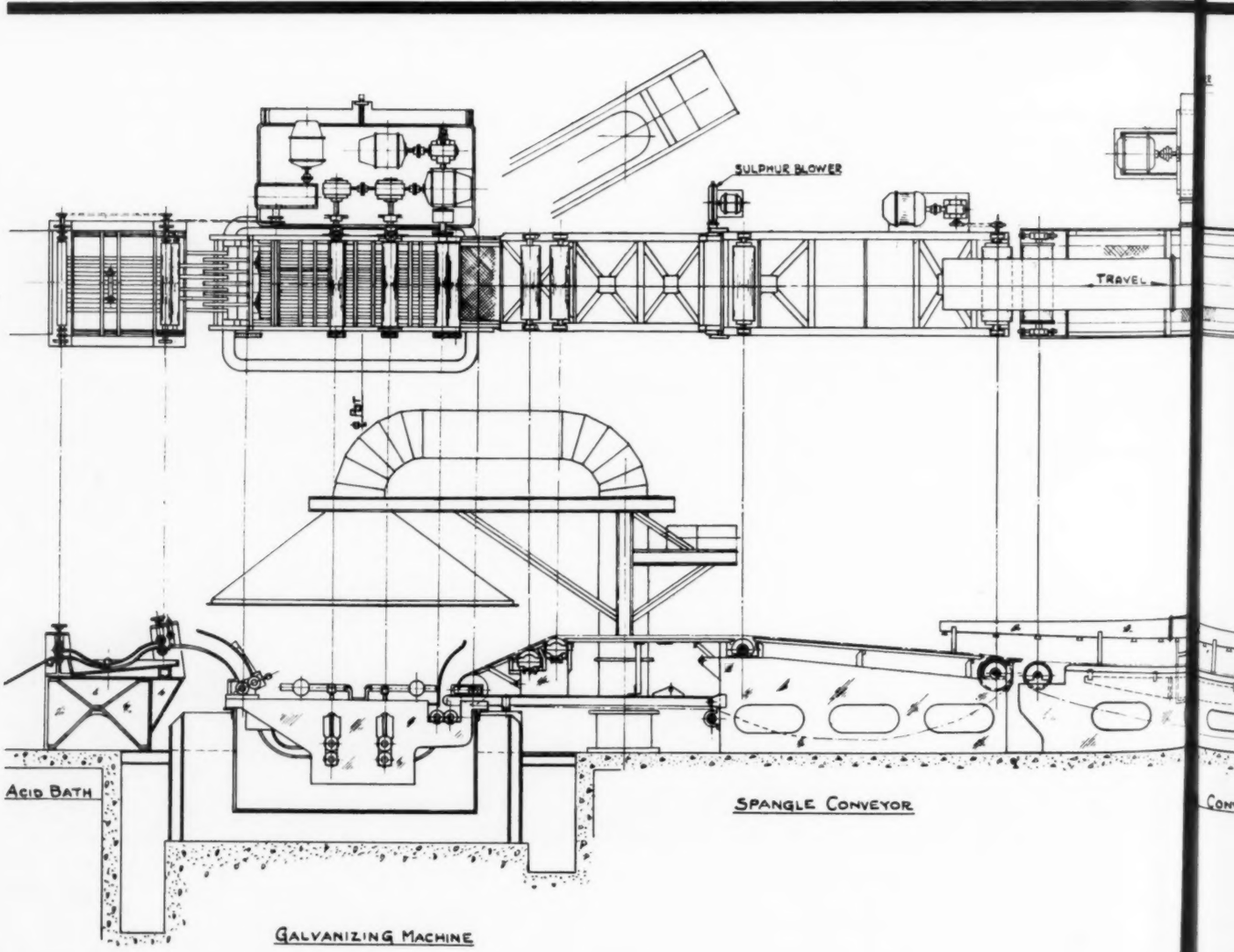


FIGURE 14—View of a modern sheet galvanizing line, taken from the delivery end.

simple to arrange the control to also discard the sheets containing holes if a means is available for detecting the hole. A photo-electric pinhole detector has been in the process of development during the past two or three years and has reached a stage in its development where it is considered very satisfactory. Approximately 20 of these pinhole detectors have been sold during the past year to be installed on lines already in existence and we know it is the intention of several of the tinplate producers to equip all of their shearing lines with these devices. A typical layout is shown in Figure 13. The device is capable of not only detecting holes as small as $\frac{1}{4}$ in. in diameter at any speed at which the shearing line operates, but also has suitable marking devices that mark the sheet containing the hole. This is done when it is desirable to discard the sheet into either the over or under gauge pile so that in future sorting of these discarded sheets the one containing the hole can be separated from those that are merely off-gauge.

The lines described so far have been those used in the processes treating the surface of the steel and in fabricating it to definite sizes. There is another general group of processing machines which had to do with applying of special coatings to the steel sheets in order to give them certain corrosion resisting properties. A typical processing line in this class is the galvanizing line. While the galvanizing process is old and was in use long before the development of the continuous hot and cold strip mills, there have been many developments within the past few years to produce better galvanized sheets. In fact, it has been the general practice to stick the galvanizing department off in some corner of the plant and very little thought was given to the improvement of the process. However, the installation shown in Figure 14 indicates that now a galvanizing machine is a modern piece of equipment installed in modern buildings and even with efficient ventilating systems installed to remove fumes.

A typical layout of a galvanizing machine is shown in Figure 15. You can note that the galvanizing machine itself is equipped with three motors, one on the entry roll, one on the bottom roll and one on the delivery roll. There is also a motor on the spangle conveyor and the first roll leveler that are synchronized with the galvanizing machine motors and receive power from a common variable voltage generator. Here there are two main reasons for the use of variable voltage equipment. The first reason is to obtain a wide range in speed and most modern galvanizing lines operate over a speed range of approximately 8 to 1. The only way such a speed range by means of rheostatic control could be obtained would be to use 4 to 1 speed range motor and then have an additional mechanical changer on the galvanizing machine to obtain the additional range. It is only at this point that the wide speed range is actually required, but it is of course desirable to have the same speed range



GALVANIZING MACHINE

on the spangle conveyor, cooling conveyor and first leveler as it gives additional flexibility of the line.

A second reason is that it makes it possible to obtain approximately synchronized speed on the three motors on the galvanizing machine over a considerable speed range and at the same time have a flexible means for making slight relative changes in the three motors in order to compensate for the relative diameters of the galvanizing rolls. This figure shows one design of galvanizing machine and another type that is widely used is one that makes use of a single motor on the galvanizing machine and then have this motor drive direct on one set of rolls and drive the other pairs of rolls through an adjustable mechanical transmission which makes it possible to obtain the relative speed of the rolls and at the same time gives a definite mechanical synchronization of the rolls. In addition to the motors already mentioned there are additional a-c. motors for driers, and blowers for cooling, removal of fumes, etc. There is also another roller leveler which is driven by a d-c. adjustable speed motor at the end of the line. This motor is not connected onto the variable voltage bus since the wide speed range is not necessary. From this discussion it is evident that the galvanizing lines have now grown up and can probably take their place along with the other processing lines in the mill.

With these brief comments on galvanizing lines, we pass over the rest of the processes of this general type including the tinning lines and all the development that is now in process on both galvanizing and tinning lines which will attempt to use the steel in coil form rather than sheet form and in which an electrolytic deposition of the metal is being attempted rather than by the hot dip process.

A few comments will perhaps be of interest on the machine shown in Figure 16. This is one of several forms of polishing machines that are being developed at the present time and are used primarily in the polishing of stainless steel. On this machine the polishing wheels themselves are driven by constant speed a-c. motors and present no problem so far as the electrical end of the equipment is concerned. However, the two reels on each end of the machine do present a rather unusual and interesting problem. It is evident that as the steel flows from one end of the machine to the other, that the diameter of the unwinding coil is constantly decreasing and the diameter of the winding coil is constantly increasing so that the relative speed of the two motors is constantly changing and there is no motor on this line which runs at a constant speed, and which can be used as a base from which to control the winding and unwinding reel motor. While various complicated schemes of regulators, etc., have been developed in an attempt to solve this problem, we believe that the simplest solution is indicated on this installation. Here a rider rheostat is supplied for each reel where the

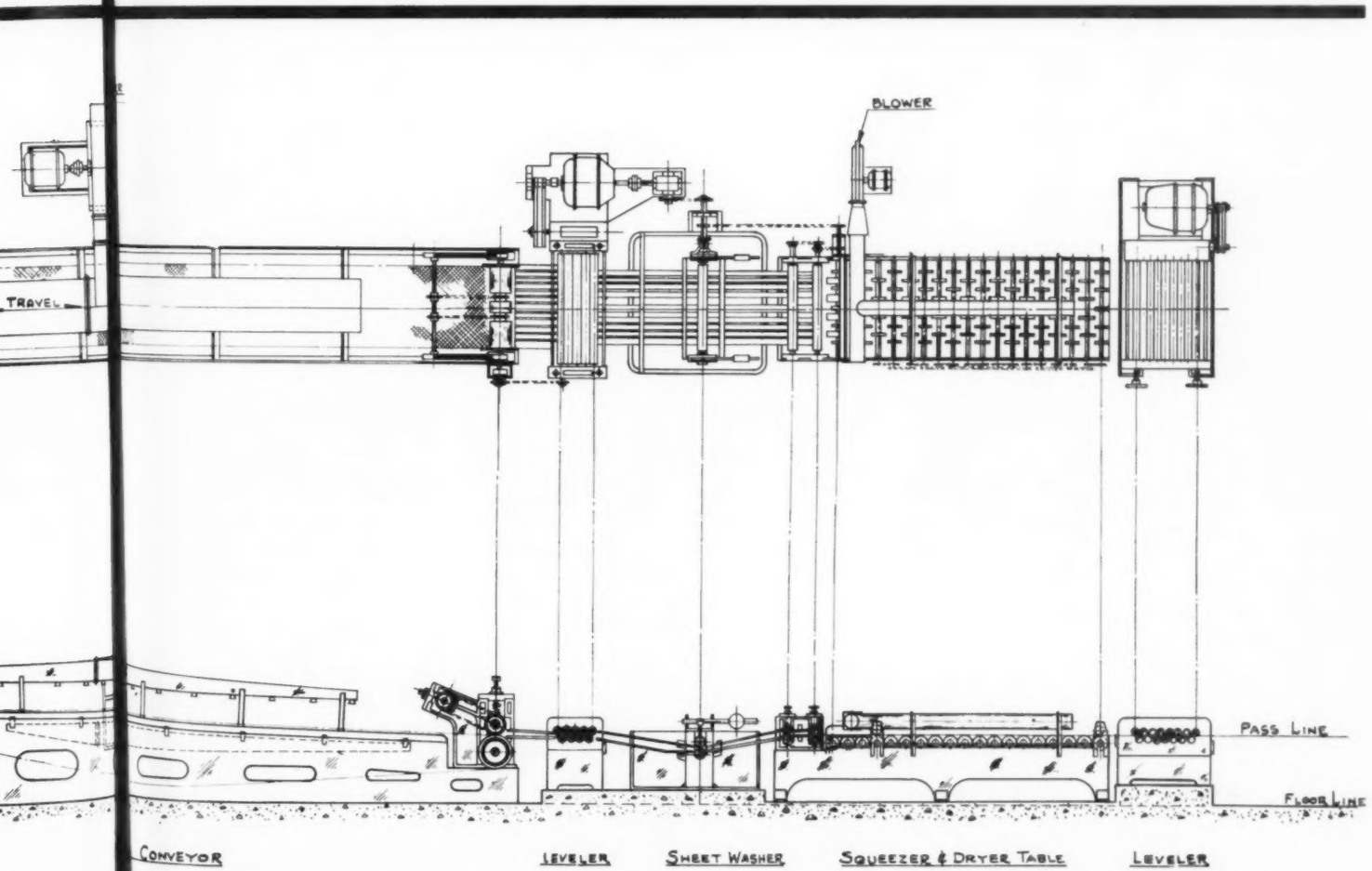


FIGURE 15—Typical layout of a modern 64 in. galvanizing line, using double bottom rolls in the pot.

FIGURE 16—This machine is one of several forms of machines under development for polishing stainless steel.

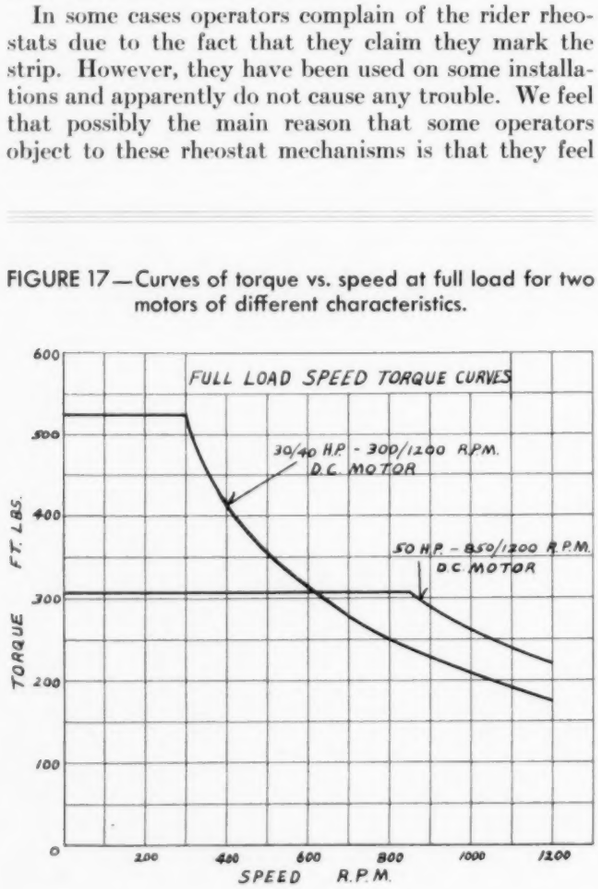
rheostat of the reel motor automatically changes its position with the change in diameter of the coil and adjusts the speed of the winding reel motor to give approximately constant speed of the strip. The unwinding reel motor is then supplied with a constant current regulator to maintain a constant tension in the strip. Since the direction of the strip through the machine can be reversed, a rider rheostat is supplied for both the winding and unwinding reel motors and the control circuits are arranged so that the constant current regulator to provide back tension is automatically transferred from one motor to the other.

In some cases operators complain of the rider rheostats due to the fact that they claim they mark the strip. However, they have been used on some installations and apparently do not cause any trouble. We feel that possibly the main reason that some operators object to these rheostat mechanisms is that they feel they are in the way and prefer electrical equipment that does not make use of them.

From my discussion of the various types of processing lines, it is evident that the trend is toward the use of variable voltage control on this type of equipment. One point that always causes considerable discussion when applying motors for a variable voltage application, especially after the past practice has been to use 4 to 1 speed range d-c. motors with rheostatic control, is the proper horsepower rating and speed range of the motor to use on variable voltage.

The reason that there are several points to be considered is evident by referring to Figure 17. Curve A is the speed torque curve when carrying full load current of a 30/40 hp., 300/1200 rpm. motor. This is a typical rating of a motor that might be used on a leveler in a shearing line with rheostatic control. From this curve you can see that the full load torque of the motor at 300 rpm. is 525 lb. ft. while the torque has been reduced to 175 lb. ft. when the motor is speeded up to 1200 rpm. Since this is the inherent motor charactersitic of a d-c. adjustable speed motor, it has been more or less the custom in the past to do the heavy work on the leveler that required high torques at low speed and then as the work to be done decreased, the leveler would be speeded up to a value that would not exceed full load current. This has been the standard practice over a period of years and it is the natural practice of a machinery builder to state that when they transfer over to variable voltage control they want the same torques at all speeds that they had when using rheostatic control.

FIGURE 17—Curves of torque vs. speed at full load for two motors of different characteristics.



Now for the sake of comparison, we have drawn on the same curve the speed torque characteristics of a 50 hp., 850/1200 rpm. motor that might be typical of a rating that would be used with variable voltage control. In other words, there is only about 50 per cent speed range by field control and the remaining control, say to get speeds down to 300 rpm., would be obtained by means of voltage control. From these curves you can see that the 50 hp. motor in the speed range from 300 rpm. up to about 600 rpm. can develop less torque than the 30/40 hp., 300/1200 rpm. motor. The question that must be settled then is whether the 50 hp. motor is large enough on a processing line to replace the 30/40 hp., 300/1200 rpm. motor. Whether or not it is large enough depends upon whether the speed torque characteristic of the 300/1200 rpm. motor is actually required. The experience that we have had with modern processing lines especially on lines such as the cleaning lines, is that the high torques available at the low speeds are not required and that the motor is never carrying its rated hp. load until it reaches the higher speeds. Under conditions such as this, the 50 hp. motor is really more liberal than the 30/40 hp. motor was under the rheostatic application as it will develop more torque continuously from 600 rpm. up to 1200 rpm. However, the actual physical size of the 50 hp. motor is smaller than the 30/40 hp. motor and is less expensive. The overall cost of variable voltage is practically always somewhat more expensive than rheostatic control due to the cost of the motor-generator set required.

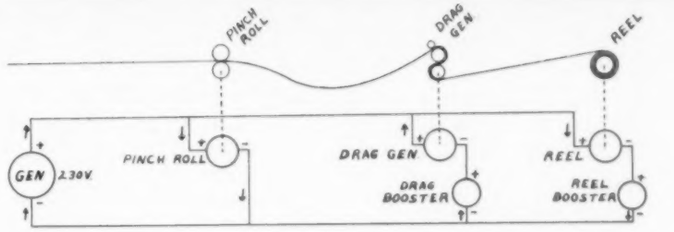
Another point which should be considered in applying motors to lines of this type is the matter of speed regulation and the amount of speed range that can be obtained by means of voltage control. While it is quite

often standard practice to design the generator rheostats that go along with a variable voltage control to give about 50 volts, the speed regulation of a motor under this condition is very bad and if the motor was called upon to exert very large torques, it might actually stall. Another point that should be considered is that the speed regulation of different sized motors will vary. This is partially due to the fact that the larger the motor, the less is usually the IR drop of the armature at full load current. On small motors this IR drop may be as much as 20 volts at full load current and on large motors may be as low as 3 or 4 volts. While this amount of variation is not particularly noticeable at 230 volts, it becomes a very large portion of the total percentage of speed drop when operating down at 50 volts or less, and if accurate speed relations are to be maintained down at these low values, the points must be accepted and proper arrangements made to compensate for them.

One type of line in which this condition is especially noticeable is on a line such as a cleaning line where the normal running speed is high and yet where it is desirable at times to run at a slow threading speed. On a cleaning line this is necessary due to the fact that when taking the two coil ends through the line where they have been welded together there is danger of the welds catching and tearing apart. Therefore, the line is run at low speed. If the line is reduced down to say, 50 volts on the main generator, the information contained in Figure 18 shows the change in relative speed when changing from 230 to 50 volts. This is particularly noticeable in the cleaning line due to the fact that the drag generator is used. The relative speeds of the various motors and generators depend upon the counter emf. developed in the armature of each machine. The calculations on Figure 18 indicate what these relative changes in speed are and we have indicated on the drawing the addition of booster generators in series with the drag motor and the reel motor which will compensate for the various IR drops of the system and thus make it possible for the counter emf. of the various motors to remain constant at any generator voltage. If these boosters are supplied and voltage is properly adjusted, the motor speed of the line can then be changed over any range and the relative speeds will not change so it is not necessary to operate the vernier adjustments to maintain the loop between the pinch roll and the drag generator.

The use of a booster is important on reel drive where the motor is also working at weak field due to the operation of the constant current regulator. Also, for operation of the constant current regulator, a permanent resistance is connected in series with the motor which also inserts an additional IR drop in that particular motor circuit. Due to the fact that the reel is worse than any other items due to the fact just mentioned, it is rather common practice to use a booster generator in series with the reel motor which will develop say, 25 to 30 volts.

This booster generator can be installed and its voltage set for a given amount which remains constant independent of voltage adjustment of the main d-c. generator and therefore compensates entirely for the IR drop of the reel motor. This booster generator also can be used to compensate for the reel inertia on acceleration and deceleration. Since the inertia of the reel is

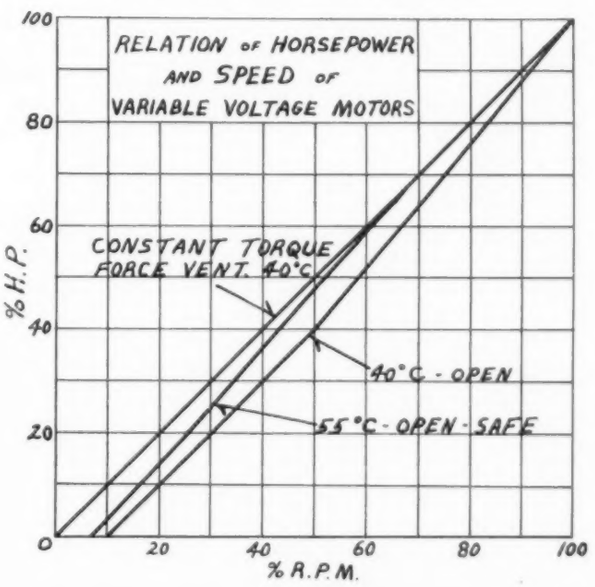


GEN. VOLTS	PINCH ROLL MOTOR			DRAG GENERATOR			REEL MOTOR		
	I.R. DROP	C.E.M.F.	SPEED	I.R. DROP	C.E.M.F.	SPEED	I.R. DROP	C.E.M.F.	SPEED
230	5	225	1150	5	235	1150	15	215	1150
150	5	145	741	5	155	758	15	135	722
100	5	95	486	5	105	514	15	85	455
50	5	45	230	5	55	269	15	35	187

FIGURE 18—Chart showing effect of IR drop on relative speeds of motors at different voltages in a processing line.

usually considerably larger than the inertia of the other drives in the system, it tends to lag on acceleration and to lead on deceleration. Therefore, the booster generator voltage can be arbitrarily raised during the accelerating period to give additional impetus to the reel motor and lowered or actually reversed on deceleration to keep the motor from tending to run faster than the rest of the line. This idea was first applied to the reels on tandem and single stand cold mills and worked out so successfully that the same idea has been applied to the reels of these processing lines. As stated above, the speed

FIGURE 19—Curves showing relation of horsepower and speed of variable voltage motors.



range of most of the processing lines is sufficiently low that it is not necessary to compensate for the IR drop of the remaining motors, but in case a very wide range of operating speed is demanded, a booster generator can be supplied for each main d-c. motor and its voltage can be adjusted after installation to exactly compensate for the IR drop of the particular circuit and thus make the speed of all motors almost directly proportional to changes in the main generator voltage.

Another point that tends to make the speed of all of the d-c. motors vary over a wide range in load is that the generator itself has a very drooping voltage characteristic at low voltages unless it is equipped with a series field to give compound characteristics. It is our usual practice on lines of this type to supply a series winding on the generator and have it on such a value that it makes the motor flat compound wound at around 50 to 75 volts. This feature tends to help in getting the line started especially if there are some special applications that may have one or two of the motors that may become jammed and it is necessary to inch the motors in either forward or reverse direction to get rid of a cobble.

I have previously indicated that when a variable voltage scheme of control is used to obtain a range in delivery speed that it results in a constant torque application of the motor. This statement is not true where the motor must operate over a very wide range of the speed control by means of reduced armature voltage. This point is illustrated in Figure 19. In this curve I have plotted the percentage of normal horsepower that a motor will develop at any given percentage of its normal speed. One curve shows the per cent horsepower developed at any given percentage of normal speed when the motor is force ventilated, and you will note that here the motor is actually a straight constant torque application since it receives effective ventilation at any motor speed.

However, if the motor depends upon the rotation of the armature itself for its ventilation, then the effectiveness of this ventilation decreases with a decrease in speed and the motor is inclined to operate at a higher temperature at lower speeds with a constant armature current. The second and third curves indicate the maximum horsepower that can be expected at any given speed at a 55 degree C. rise which represents a safe operating temperature and the other curve represents the horsepower that can be developed with the motor operating at its normal guaranteed temperature rise of 40 degrees C. continuous open.

When applying motors to operate over a wide speed range, they will operate satisfactorily if the horsepowers are selected in line with the information contained in Figure 19.

In this discussion of processing lines I have tried to give a general discussion on the lines themselves and devote most of the time to pointing out features of control and the proper characteristics of the rotating equipment to produce the most satisfactory processing line. These lines are very important links in a long chain and deserve the same consideration and attention given to selection of the rolling mills themselves.

Gas Mixing and Distribution

AT GREAT LAKES STEEL CORPORATION

(*Continued from page 25*)

impulses proportional to the gas flow, and send them out through small connector tubing to piston type senders, which are mechanically connected to and simultaneously operate dampers in both the hot and cold air ducts.

As these damper operators are both full compensating, we obtain air flow proportional to the gas flow, and efficient combustion is thus established and maintained.

Remote manual adjustment in control is provided by means of relays installed in the impulse lines between the sender regulators and the receiving regulators.

The advantages of automatic furnace control may be summarized as follows:

1. After the setting has been made for certain furnace output demand, which has previously been determined by gas analyses, automatic control will maintain this fixed combustion resulting in a product of highest quality. Manual control which involves the human element to a marked degree, and is dependent wholly on the ability of the heaters who operate the furnaces in setting the best combustion for mill demand.

2. By duplicating already established operating conditions for the furnaces, a uniform product is obtained, which in turn increases production.

By maintaining ideal and uniform combustion conditions, best results are obtained.

3. A decrease in cost of production by maintaining uniform atmospheric conditions in the furnace, results in maximum heat liberation from fuel which in turn gives a lower fuel consumption per ton of steel heated.

4. Controlled atmosphere is partially responsible for the reduction of scale formation. It also permits and controls the desired atmosphere which in turn lends itself to the metallurgical result desired.

We have obtained a much better sheet from normalizing furnaces, which can again be traced to a steady normal gas pressure, due to furnace atmosphere conditions. Lower fuel costs for operation of normalizing has been effected together with an increase in furnace production. In the box annealing furnaces, equipment for the handling and burning of fuel oil has been eliminated, due to a complete changeover to mixed gas.

The uses of mixed gas in our plant has given advantageous heating performance, simultaneously with an improved economy.

Philadelphia Section
A. J. FISHER

Birmingham Section
H. T. WATTS

Chicago Section
H. R. MIDDLEBROOK

A. I. S. E. District Section Chairmen

H. T. Watts was born at Louisville, Kentucky, and attended the public schools in that city, receiving his bachelor's and master's degree in mechanical engineering at the University of Kentucky in Lexington. Mr. Watts was first employed at the Youngstown Sheet and Tube Company in Youngstown, Ohio, in the steam engineering department. He later became assistant steam engineer for that company.

Mr. Watts transferred to the Otis Steel Company in Cleveland, holding the position of steam engineer for that company. He joined the forces of the Surface Combustion Corporation, and was stationed at Pittsburgh in sales work and development. He was later appointed superintendent of power for the Gulf States Steel Company at Gadsden, Alabama, and later became combustion engineer for the same concern. This company was absorbed by the Republic Steel Corporation in 1937, and Mr. Watts holds the same connection with the Gulf States Steel Division of Republic.

H. R. Middlebrook, assistant division superintendent of maintenance for the Gary steel works of Carnegie-Illinois Steel Corporation, has been in the employ of this company for the past thirty years. Born in Manistique, Michigan, Mr. Middlebrook received his elementary and high school training in his home town. After attending the University of Michigan, he completed his electrical training at Bliss Electrical School in Washington, D. C.

Mr. Middlebrook began his steel mill career as helper in the power house, then switchboard operator, train motor foreman, power superintendent, assistant electrical engineer, and in February, 1939, he received his present position of assistant division superintendent of maintenance.

T. B. McElray was born in Youngstown, Ohio, and has resided there all his life. After graduating from public school, he was employed by the W. B. Pollock Company for about eight months, leaving to enter the employ of the Carnegie Steel Company under the supervision of B. R. Shover in 1900 as oiler. Mr. McElray was advanced to motor inspector, shop foreman, power house foreman and assistant superintendent, having charge of all electrical construction and operation of the Youngstown district. He was appointed superintendent of electric light and power, Youngstown district, in May, 1932, being responsible for the electrical installation of the 43 in. strip mill at McDonald, Ohio. It was at his suggestion that the assembling of control boards complete in groups at the factory was instigated.

Mr. McElray's education was acquired by home study and at the Y.M.C.A. night schools.

A. J. F. MacQueen was born in Thessalon, Ontario, Canada, in 1901. Mr. MacQueen attended public schools in Sault Ste. Marie, Ontario, and then worked for a period in the electrical department of Algoma Steel Corporation, Ltd. He attended Toronto University and was graduated in 1925 with a B.A. Sc. in electrical engineering. The following two years were spent in General Electric Company's test course in Schenectady.

In 1927, Mr. MacQueen went with the Sharon Steel Corporation in the electrical department. He was made assistant chief electrician of the Sharon plant in 1930. In 1936 he transferred to the Rotary Electric Steel Company in Detroit as chief electrician, and in 1937 he was promoted to superintendent of maintenance in charge of the electrical and mechanical departments.

A. J. Fisher was graduated from the Colorado State preparatory school and later from the University of Colorado, college of engineering, with a degree of M.E. in mechanical engineering. Mr. Fisher began his steel mill employment with the Bethlehem Steel Company at the Maryland plant as assistant master mechanic of the sheet and tin mill division in 1924. After serving in several capacities in various departments, Mr. Fisher became fuel engineer in 1929, holding that position at the present time.

C. L. McGranahan was graduated from the Pennsylvania State College in 1916 with a bachelor of science degree in civil engineering. In the same year, Mr. McGranahan started his steel mill career with the American Sheet and Tin Plate Company. He worked in various positions with the company at various plants until 1931, allowing for one year World War service. In the year 1931, he joined the Inland Steel Company as superintendent of the company's Indiana Harbor hot strip mill, resigning in February, 1936, to take his present position as assistant general superintendent with the Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania.

Detroit Section
A. J. F. MacQUEEN

Pittsburgh Section
C. L. McGRANAHAN

Cleveland Section
T. B. McELRAY

Some Modern Applications of BOILERS in STEEL MILLS

By D. N. MAUGER, *Executive Assistant*
BABCOCK AND WILCOX COMPANY
NEW YORK, NEW YORK

Presented before A. I. S. E. DETROIT DISTRICT SECTION, January 9, 1940

▲ IN the years 1910 to 1930 there were installed in iron and steel mills a tremendous amount of heating surface in boilers. Recent improvements in the efficiency of prime movers and boilers, together with the increased rating of boilers, has greatly reduced the amount of heating surface of old equipment that would have been required to be replaced without these improvements. Yet the fact remains that through the depression period, 1930 to 1939, only a relatively small amount of replacement and modernization has occurred, so that the steel mills today are faced with replacement of a large amount of boiler heating surface that is 25 to 30 years old.

How this is to be done is a matter of individual consideration for each plant, taking into consideration the balance between fuel, steam and electric power; the investment, including water treating plant; whether or not there are waste fuels available as against purchased fuel. All these facts largely determine whether or not the replacement will be high pressure or low pressure.

A survey of thirty-four proposals for boilers for the iron and steel industry made by our company over the last three years shows what our customers are thinking about and reveals the following:

Pressures—There were 19 proposals in the pressure range of 160 to 275 lb.
4 proposals—450 to 525 lb.
5 proposals—650 to 725 lb.
6 proposals—850 to 975 lb.

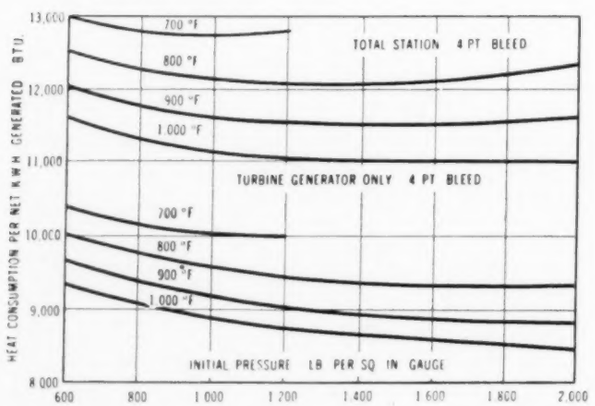
This indicates that one-half were for low pressure and, no doubt, were dictated by a desire for more modern and efficient equipment to replace older obsolete equipment.

Types of installation:

General steel mill base load, 200 lb. to 275 lb.—low superheat	6
Process and heating, 200 lb. saturated and low superheat	5
Rolling mill,	
Low pressure and temperature	2
High pressure and temperature with topping turbine—675 lb.—660 degrees	1
Strip mill,	
Low pressure and temperature	1
Blowing engine,	
Low pressure and temperature	2
Power,	
All the way from 160 lb.—500 degrees to 900 lb.—840 degrees	17
(Of this number 8 were for topping turbines and 1 was for a condensing turbine at high pressure and temperature.)	
Fuels,	
Pulverized coal alone	12
Pulverized coal and blast furnace gas	5
Pulverized coal and coke oven gas	2
Blast furnace gas alone	3
Coal or coke breeze on chain grate stokers	11
Natural gas	1

In the early days the iron and steel mills were adjacent to blast furnaces and coke ovens. The waste fuels of blast furnace gas, coke oven gas and coke breeze were burned under boilers, and some blast furnace gas was also used in gas engines and the power thus developed was sufficient to run the mills. In recent years the use of more electric drives in rolling mills and strip mills

FIGURE 1—Curves showing attainable heat rates of total station and generator only, with high pressures and temperatures.



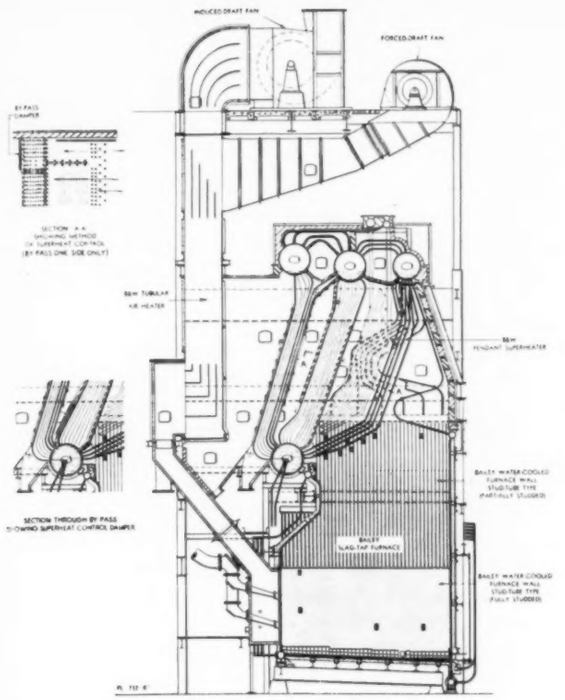


FIGURE 2—Side elevation of one of the units installed at the Weirton Steel Company, with capacity to operate a 10,000 kw. turbo-generator.

has increased the demand for electric power beyond the capacity of the waste fuels to generate it and more and more purchased fuel or power has been necessary.

This situation has brought about improvements in the steam generating end to gain better efficiency with less investment cost. This has meant running boilers at high ratings with water walls, economizers and air heaters.

The furnace, therefore, has come in for a great deal of attention because in the early days blast furnace gas and pulverized coal were not burned together in the same furnace but with the large number of boilers installed one set would be fired with blast furnace gas and another set with coal in one form or another.

Normal operation back in 1916, say, was about 50 per cent power from blast furnace gas and 50 per cent power from coal when the gas was available. When the gas went off about 70 per cent of the total power was from coal. This represented an increase of 40 per cent in the power from coal from the normal operation to the gas-off operation.

Today the picture has generally changed in that normal operation is about 80 per cent power from blast furnace gas and 20 per cent power from coal. In the gas-off operation about 65 per cent of the total power is from coal. This represents an increase of 225 per cent in the power from coal from the normal operation to the gas-off operation.

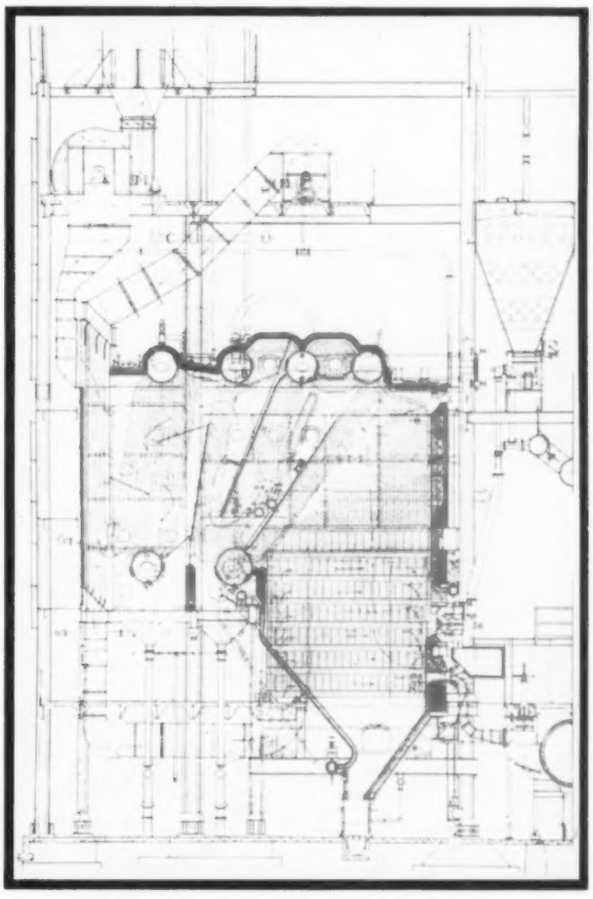
There was a paper by Kerr and Hardgrove published in the IRON AND STEEL ENGINEER in August, 1932, in which calculations were given for the limits of furnace exit gas temperatures with both fuels. This showed that the limit of furnace exit gas temperature is reached with blast furnace gas at far higher liberation rates per square foot of cold surface in the furnace than in the case of pulverized coal firing. They estimated that heat liberations of 600,000 Btu. per sq. ft. of cold surface should be attainable with blast furnace gas as compared to 200,000 with pulverized coal having an ash fusion temperature of 2200 degrees F.

Improvements in steel mill practice have brought about the requirement that these two fuels must be burned in the same furnace. The temperatures developed in the zone of combustion when burning coal alone at present-day rates with low fusing temperature ash coals require water cooled furnaces with sufficient cooling to prevent serious slagging of the boiler surfaces.

Where large portions of steam are used for mechanical power, process and heating at low pressures, a superimposed power plant with non-condensing turbine should make, in many cases, a favorable showing in savings, especially where a plant has no waste fuel available.

Figure 1 shows some curves of attainable heat rates with higher pressures and temperatures. In these curves the initial pressure at the turbine is plotted against Btu.

FIGURE 3—Five boilers of this type, rated at 1460 hp. each burn blast furnace gas and pulverized coal at Tennessee Coal, Iron and Railroad Company.



consumed per net kwh. generated at four different total temperatures.

The four curves at the top give heat rates attainable, with four bleed points on the turbine, for the total station and show that, with the exception of 1000 degree F. steam, the heat rates increase above 1300 lb. pressure. This is due to the power required to drive the feed pumps.

The four curves at the bottom are for the turbine generator only with four bleed points and show a decrease in heat rates with increase in pressure above 1300 lb.

Most central station topping units operate at about 1250 lb. pressure and 900 to 950 degrees F. total temperature.

While it is possible for certain set-ups in steel mills to justify steam conditions up to 1300 lb. and 950 degrees F., which the curves show would give an attainable heat rate for the whole station of 11,250 Btu. per kwh., the general tendency seems to be to go to 900 lb. and 850 degrees F. The curves show an attainable heat rate for the whole station of 12,000 Btu. per kwh.

The reason for this probably is that it is impossible to justify the increased investment in boilers, feed pumps, turbines, piping and feed water treating with the load factor available as compared to a public utility whose business is making kilowatts.

A typical example of this kind of replacement is that of the Weirton Steel Company about which considerable has been written. This plant had no outside source of power. When they decided to install a modern hot and cold strip mill for the rolling of light gauge steel they were faced with a large increase in power generation.

There were two boiler plants inter-connected electrically but with no steam tie-in. Plant (A) had 10,000 boiler hp. developed capacity in 160 lb. pressure boilers 25 years old which had reached a stage where extensive boiler rebuilding was necessary. There were two 3000 kw., 150 lb. turbo-generators and three 1000 kw. mixed and low pressure turbo-generators installed in this plant, which in addition to the electric load supplied a substantial amount of steam for process work and mechanical drives.

Plant (B) was newer—10 to 15 years old—and contained 225 lb., 500 degree F. boilers fired partly with coal, both pulverized and underfeed stokers, and a large part by by-product fuels such as blast furnace gas, coke breeze and open hearth waste heat.

The steam was used for electric power in five 7500 kw. turbo-generators at 215 lb. and 100 degrees F. superheat. The balance went for process and mechanical drives.

They decided to keep Plant (A) as a standby and to install two high pressure high temperature boilers and

FIGURE 4—Side elevation of one of six 1800 hp. boilers, fired with pulverized coal and blast furnace gas, at Campbell works of Youngstown Sheet and Tube Company.

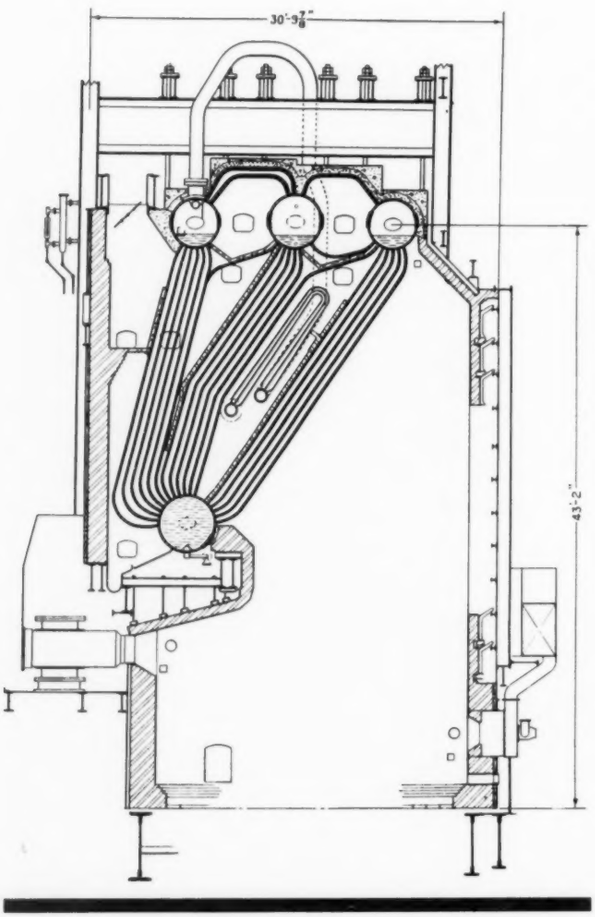
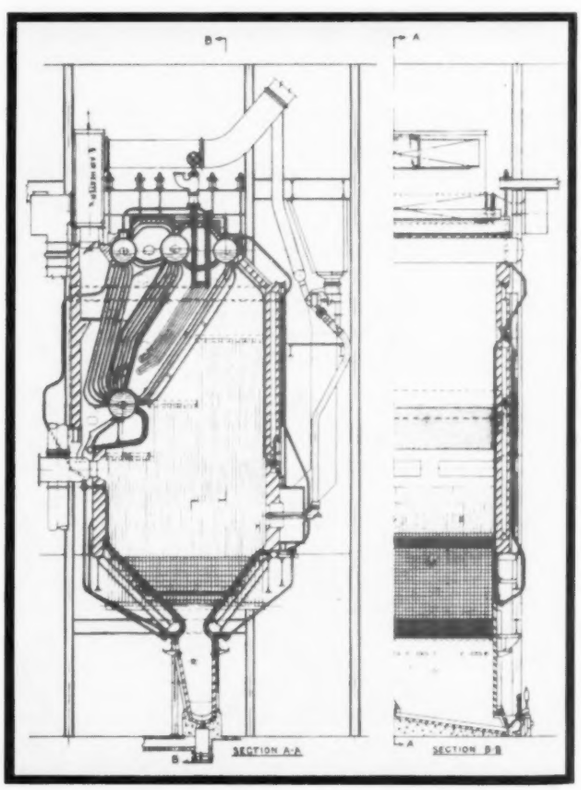


FIGURE 5—The boilers of Figure 4 were modernized by the installation of water walls, new coal burners, new superheaters, steam scrubbers, etc.



one 10,000 kw. super-imposed turbine for 800 lb. and 820 degree F. on account of the large investment already made in power generation.

This new extension went into service in June, 1936, using 100 per cent Ohio River water treated in their existing feedwater plant and furnished the additional power required as well as the necessary amount of steam to replace the 150 lb. plant.

Figure 2 shows a side elevation of one of the two units each of which was large enough to operate the 10,000 kw. turbo-generator at full rating continuously and at 12,500 kw. peak.

While there were two boilers and one turbine to start with they do not intend adding an additional boiler when they install the second turbine. The requirements of the mill require that the output of one boiler be available 100 per cent of the time.

The boilers are 4-drum bent tube, 900 lb. drum pressure each designed for 315,000 lb. continuous output, 400,000 lb. peak, with superheaters to give 815 degrees F. at 315,000 lb. output and fired with pulverized coal of 12,500 Btu. and 2200 degree F. softening temperature ash. The furnace is completely water cooled with intermittent slag tap floor. A tubular air heater supplies air at 550 degrees F. at maximum capacity. Overall efficiency is 84.9 per cent at 315,000 lb. capacity and 83.8 per cent at maximum capacity.

Mention has been made of firing blast furnace gas in combination with coal. The Tennessee Coal, Iron and Railroad Company pioneered in this development at its Ensley, Alabama, blast furnace plant back in 1922. At that time they installed six bent tube boilers, 834 rated hp. each, 250 lb. pressure, 150 degrees F. superheat equipped with brick furnaces. Blast furnace gas was

FIGURE 6—This installation consists of a 615 hp., 250 lb. pressure unit set over a chain grate stoker for burning slack coal and coke breeze.

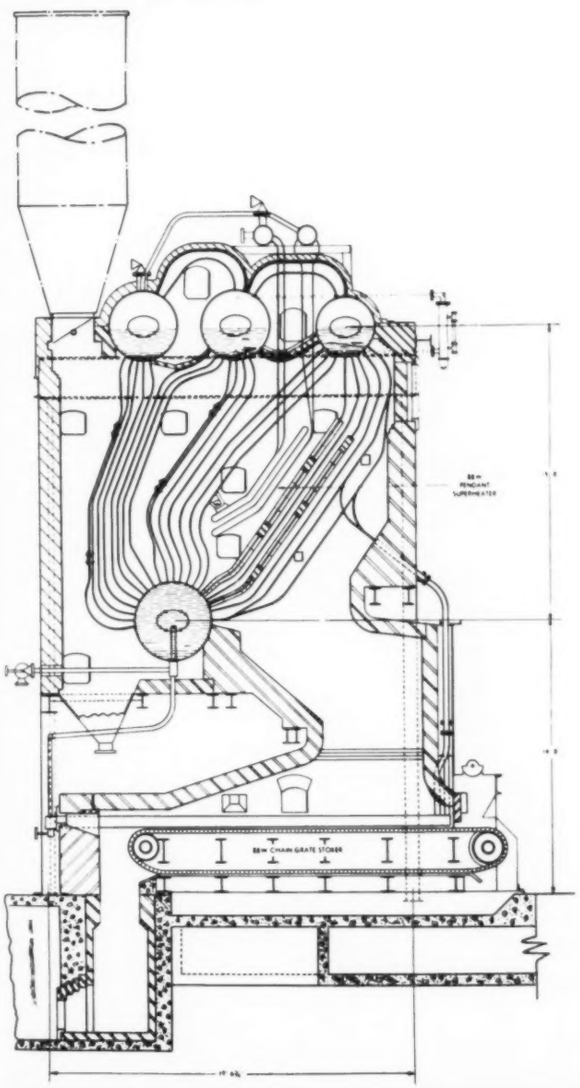
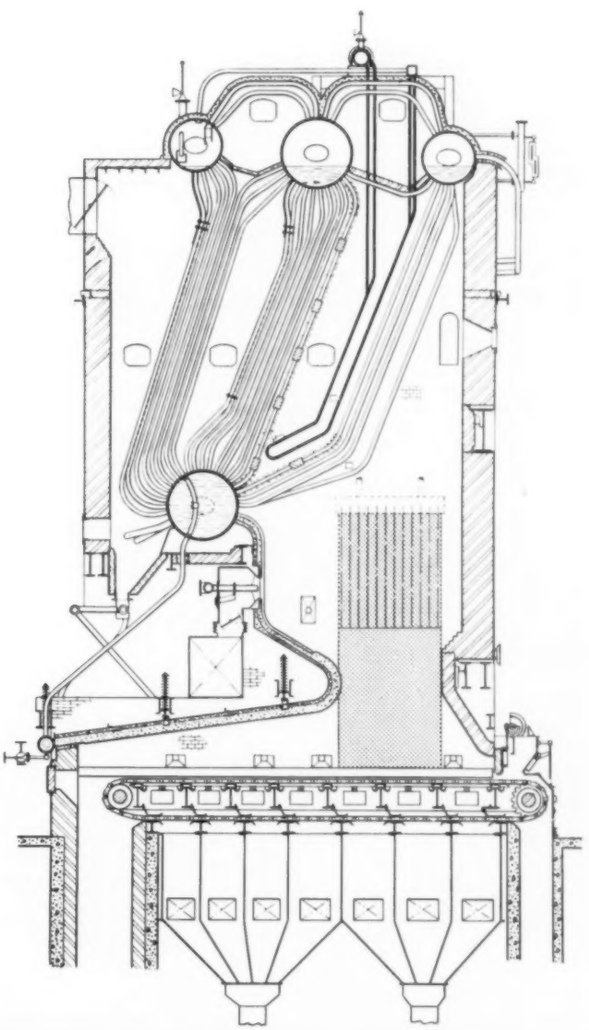


FIGURE 7—Side elevation of one of two 860 hp., 250 lb. units set over a chain grate stoker for burning coke breeze.



fired through the front and pulverized coal through the top arch just under the front drum.

Figure 3 shows the development of this idea at Fairfield blast furnace plant of this company, which went into operation in 1928. The cross section shows one of five bent tube boilers of 1460 rated hp., 375 lb. drum pressure, 200 degrees F. superheat. The blast furnace gas was fired through the lower burners and pulverized coal through the upper burners from a central storage system. The furnace had air cooled side walls and water cooling down one face of the hopper bottom, also water cooling up the face of the front wall above the burners. A two-drum economizer and air heater were used behind the boiler.

With the increased efficiency it was possible to increase the electric power generated from surplus blast furnace gas per ton of product about 50 per cent over what was average practice in the previous decade. There are records of as high as 7000 hp. on blast furnace gas alone from one of these boilers, which is approximately 500 per cent rating.

An example of what can be done to modernize existing boilers which have not yet reached obsolescence is the revamping job at the Campbell Works of the Youngstown Sheet and Tube Company at Youngstown, Ohio, which went into service in 1937.

Figure 4 shows the side elevation of one of six bent tube boilers rated at 1800 hp., 415 lb. pressure, fired with pulverized coal and blast furnace gas and having a maximum capacity of 165,000 lb. per hr.

Figure 5 shows what was done to two of these boilers. Water walls were installed on four sides of the furnace with hopper bottoms. Five new circular burners and feeders were installed in the front wall and connected to the existing central storage system for pulverized coal firing. The existing pressure blast furnace gas burners were installed in the wall opposite the pulverized coal burners. New superheaters were installed to give 700 degrees F. at 330,000 lb. capacity on coal and 758 degrees F. at 190,000 on blast furnace gas.

Two rows of boiler tubes were removed to allow room for the larger superheater and slag screen tubes were installed in the front bank. Steam scrubbers were installed in the rear drum. With the changes it was possible to double the capacity on coal. It was planned to run one unit on coal alone at high rating and the

FIGURE 8—This 2586 hp. unit was installed at Eliza Furnace plant of Jones and Laughlin Steel Corporation to meet increased power demands.

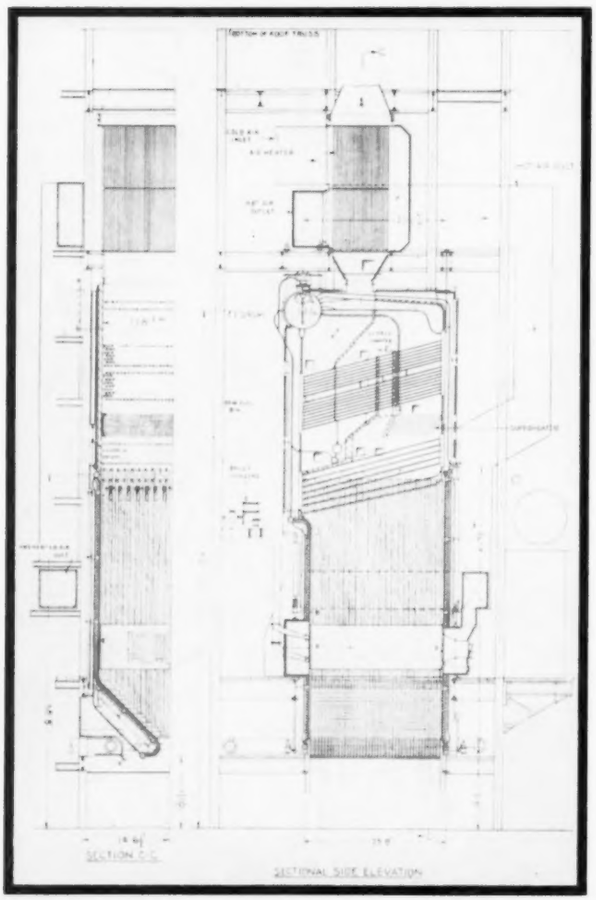
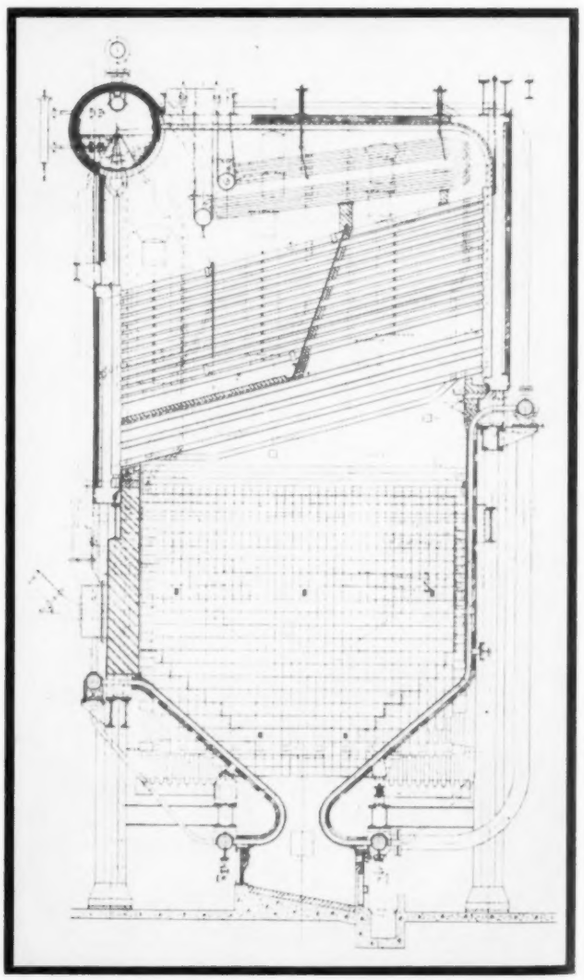


FIGURE 9—This installation at Otis Steel Company is capable of handling blast furnace gas, coke oven gas, pulverized coal and fuel oil, either separately or together.



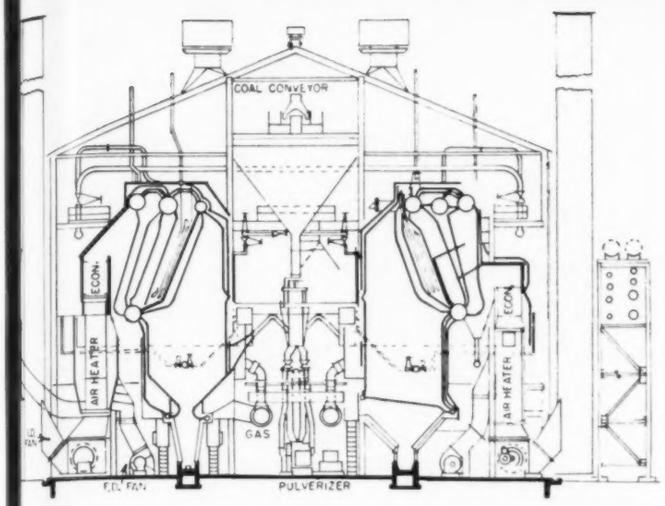
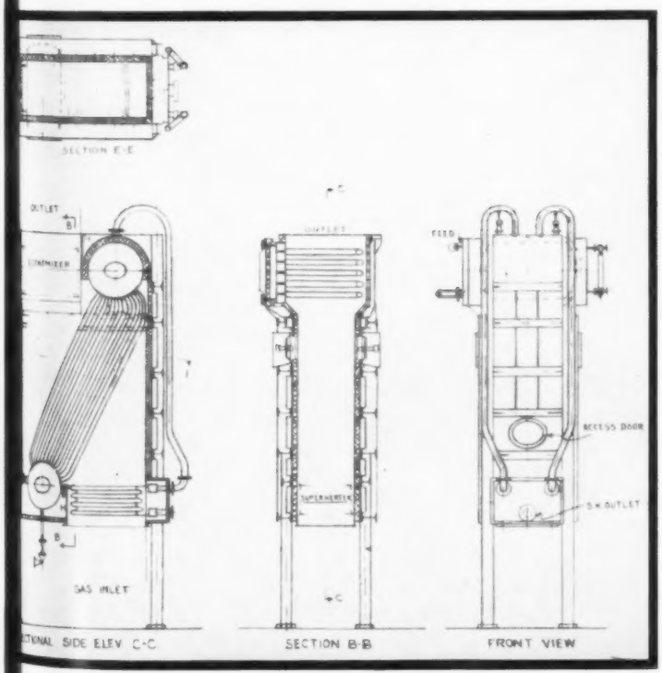


FIGURE 10—Cross-section through boiler house of Carnegie-Illinois Steel Corporation at Youngstown, Ohio, which was modernized in 1937.

other unit on 50 per cent coal and 50 per cent blast furnace gas.

I mentioned earlier that out of 34 proposals in the last three years, ten were for chain grate stokers burning coal or coke breeze. Figure 6 shows a rather simple modernization at the McDonald plant of the Carnegie-Illinois Steel Corporation at Youngstown, Ohio, consisting of a 615 rated hp. bent tube boiler, 250 lb.

FIGURE 11—This unit, at the Maryland plant of Bethlehem Steel Company, utilizes waste heat from gas engines operating on blast furnace gas.



pressure, 150 degrees F. superheat, 40,000 lb. per hr. capacity unit set over a chain grate stoker for burning slack coal and coke breeze of 10,750 Btu. using forced blast. No water cooling was used in the furnace because the maximum output corresponded to only 200 per cent of rating. Steam was used for tar atomization in billet heating furnaces, in pickling operations and general mill process use, including building heating. Although designed for 250 lb. the boiler is operated at 150 lb., the pressure of the older steam plant.

In 1938 this same corporation installed two similar units at the Irvin Works, Dravosburg, Pa. Figure 7 shows the side elevation of one of two 860 rated hp. boilers, 250 lb. pressure, 530 degrees F., 60,000 lb. capacity, set over a chain grate stoker 12 ft. 6 in. x 20 ft. 3 in. for burning coke breeze of 9871 Btu. per lb. Two multiple unit coke oven gas burners were installed below the mud drum firing through the rear water wall. Some water cooling was used in the furnace side walls and in the long rear arch.

Another rather interesting application for increasing power demands is the installation at Eliza Furnace plant of the Jones and Laughlin Steel Corporation, Pittsburgh, which went into service in 1936. They had four 450 lb. design pressure boilers each of 250,000 lb. capacity, 425 lb. pressure, 725 degrees F., at superheater outlet, fired with pulverized coal and blast furnace gas and connected to one common main leading to the turbine room with space left for a fifth unit at the middle of the line. A new strip mill was installed which had sudden power demands, when the material hit the rolls, of something like 25,000 kw. The fifth unit was installed to take this sudden demand by purposely designing the superheater with an extra 25 lb. pressure drop at 400,000 lb. output which made the drum pressure 475 lb.

A quick opening valve was placed in the line connecting the new boiler to the 425 lb. main which was only partially opened when the new boiler was delivering steam under steady load at the rate of 250,000 lb. per hr. The valve, when partially open, added a sufficient pressure drop across it to balance the new boiler against the line pressure. When the sudden demand occurred the valve opened wide and the boiler was fired harder. A 72 in. diameter drum was provided for large water storage and steam space all with the idea that the heat storage in the water would generate enough steam, when the pressure in the drum reduced suddenly, to supply the sudden demand. The arrangement worked very well, provided the operators did not let the concentration in the boiler get too high. To provide more margin in this respect steam and water cyclones were recently installed in the drum which will be described later.

Figure 8 shows the cross section of the 2586 rated hp. cross drum boiler with completely water cooled furnace, hopper bottom, interdeck superheater with provision for control of superheat over a wide range of load through a by-pass damper, and tubular air heater for 535 degrees F. at maximum rating. Pulverized fuel from a central storage system is delivered to cross-tube burners at one side and blast furnace gas to burners on the opposite side. This gas had a heating value of 89.36 Btu per cu. ft. at 60 degrees F. and 30 in. Hg. The design was such that the maximum capacity of 400,000 lb. could be generated by pulverized coal at an efficiency

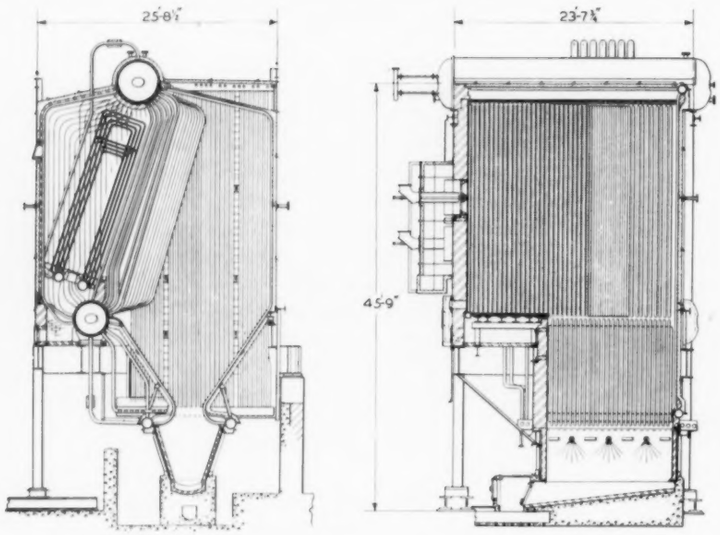


FIGURE 12—Integral furnace boilers at the Indiana Harbor plant of Youngstown Sheet and Tube Company contain 13,800 sq. ft. of heating surface.

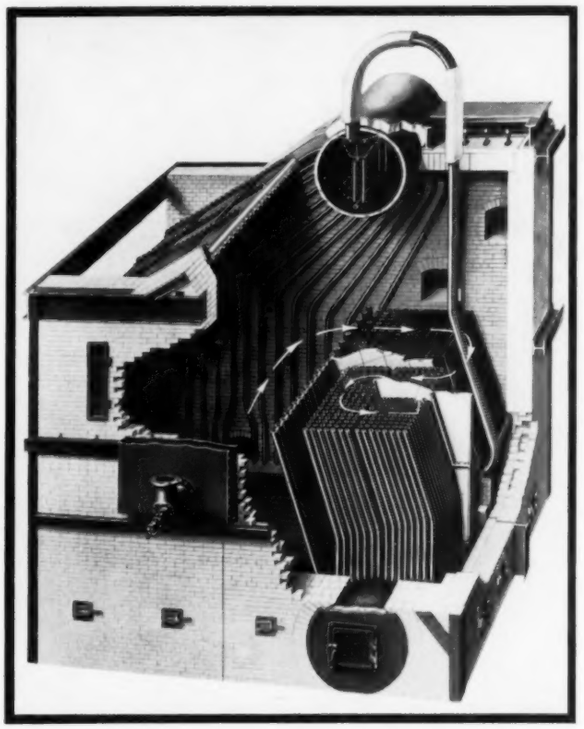


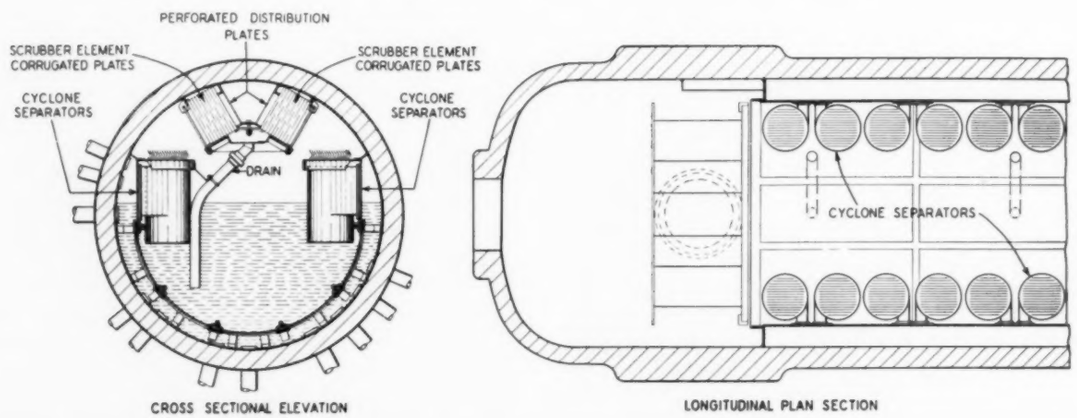
FIGURE 13—Isometric view of integral furnace boiler, showing travel of gases through the unit.

of 85.9 per cent and when blast furnace gas was burned in combination with coal the maximum steam generated by the gas was 225,000 lb. while the coal made up the balance of 175,000 lb. The efficiency of the unit with this combination of fuels was 80.7 per cent.

Figure 9 shows an interesting application for handling four fuels, either alone or simultaneously, consisting of blast furnace gas, coke gas, pulverized coal and fuel oil in the same furnace. This installation was made in 1928 in the blast furnace power house of the Otis Steel Company, Riverside Works, Cleveland, Ohio. The unit was an 1108 rated hp. cross drum boiler, 250 lb. pressure, 150 degree F. superheat and supplied steam to two 10,000 kw. turbo-generators and one turbine driven blower of 45,000 cu. ft. per min. capacity at 30 lb. pressure.

The 250 lb. line was connected through a desuperheater and pressure reducing station to the existing low pressure system supplied from an old boiler house at 150 lb. saturated which supplied steam to three blowing engines at one time and other equipment incidental to a blast furnace, skip engine, hydraulic pump, etc. The low pressure system is, however, being gradually re-

FIGURE 14—Steam and water cyclone installed in the boiler drum function to separate steam and water.



placed by the more efficient higher pressure equipment.

Figure 10 shows an example of modernization which went into service in 1937 in the Ohio Works of the Carnegie-Illinois Steel Corporation, Youngstown, Ohio. This mill is the iron and steel producing unit for the Youngstown district plants. The steam generating plants consisted of a number of 150 lb. pressure boilers; 250 lb. and 150 lb. pressure bent tube boilers, stoker fired, and a number of scattered 150 lb. blast furnace gas fired boilers. All of these latter units were replaced by four 1750 rated hp., 525 lb. drum pressure, 700 degree F. units. The pressure and temperature were selected looking towards topping turbines in the future at which time exhaust or bled steam could be fed to the existing low pressure system and balance the supply of waste heat to the low pressure boilers. Until the topping turbines are installed operation is at 265 lb. steam pressure utilized in existing equipment.

The new units are part of a program for utilization of waste fuel and are fired with blast furnace gas with pulverized coal as an auxiliary fuel. Both fuels can be fired simultaneously or separately through combination circular coal and gas burners.

Figure 11 shows an interesting application of a water tube boiler utilizing waste heat from gas engines using blast furnace gas. The design was dictated by limited space conditions where the usual shell type boiler, with gas going through the tube would not fit. The unit consists of a two-drum boiler, and has 2390 sq. ft. of heating surface, 450 lb. drum pressure; a superheater for 700 degrees F., and an economizer, all enclosed in a gas-tight casing designed to withstand 15 lb. per sq. in. pressure due to pulsation from the gas engine. The unit produces 11,000 lb. of steam per hr., utilizing 66,000 lb. of waste gas per hr. which enters at 1200 degrees F. and leaves at 432 degrees F. The efficiency is 68 per cent. The inside plates of the casing were calorized and the whole unit located out-of-doors.

Figure 12 shows an application of two integral furnace boilers now being installed by the Youngstown Sheet and Tube Company at Indiana Harbor, Indiana. Each of these units, containing 13,800 sq. ft. of heating surface, is designed for 875 lb. drum pressure; superheater to give 750 degrees F.; and air heater of 19,150 sq. ft. Each unit is fired with pulverized coal from two pulverizers, and will furnish 141,000 lb. of steam per hr. to a new topping turbine.

Figure 13 shows an isometric view of the integral furnace boiler and gives a better idea of the flow of gases through the unit. The firing, being parallel to the drum, gives a deep furnace and considerably more steam and water space than in a boiler where the drum is across the furnace. The furnace, being alongside the heating surface, saves considerable headroom and makes this unit an ideal one for modernization where space in an existing boiler house may be at a premium. In high pressure installations, on account of first cost and fixed charges, it is important to operate at a maximum number of hours per year in order to take full advantage of the savings. It is, therefore, important that the steam going over to the turbine be in a state of maximum purity so that solids carried over and deposited on the turbine blades will be at a minimum, otherwise a serious loss in the power output of the turbine will result.

Considerable research and experimental work has

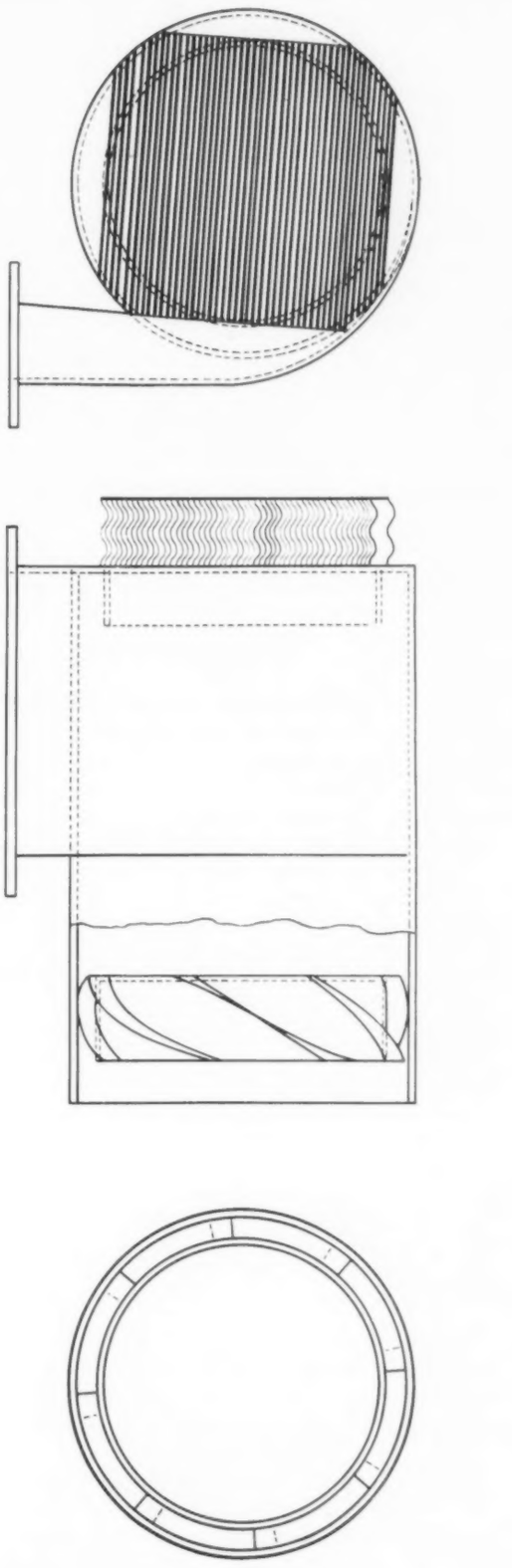


FIGURE 15—This view of the steam and water cyclone shows the turbo-vane openings at the bottom.

been carried on for some years to secure more definite knowledge of the circulation factors involved in boilers as affecting steam purity. Figure 14 shows the cylcone recently developed which was referred to earlier as being installed at Jones and Laughlin Corporation. The function of the cyclone is to separate steam from water as well as water from steam. By this I mean that it is important on high duty units to return water from the drum to the circulation of the unit as nearly free from steam bubbles as possible. That the cyclones do this has been proven on many installations. The addition of cyclones at Cincinnati Gas and Electric Company, West End Station, increased the available circulating head as much as 30 per cent.

In operation the mixture of water and steam coming up to the outlet drum of the boiler from the generating tubes and water wall risers is discharged into a manifold placed over these tubes and forming a separate compartment from the main storage and relieving space of the drum. The cyclones are attached to this separate compartment so that the mixture of water and steam enters the cyclones tangentially and whirls around. The water goes down by gravity and is discharged to the quiet portion of the drum through turbo-vane-shaped ports while the steam, with some moisture, passes upward through a series of corrugated closely-spaced scrubber plates where the entrained moisture is further separated and returned to the drum. Wide variations in the water level in the drum are possible without appreciably affecting the quality of steam from the boiler or the density of water being returned to the boiler circulation. Higher concentration of total solids can also be carried in the boiler water with the cyclones.

Figure 15 shows another view of the cyclone with the turbo-vane openings in the bottom visible.

DISCUSSION

PRESENTED BY

A. J. F. MacQUEEN, *Superintendent of Maintenance*, Rotary Electric Steel Company, Detroit, Michigan.

D. N. MAUGER, *Executive Assistant*, Babcock and Wilcox, New York, New York.

W. H. COLLISON, *Assistant Superintendent*, Coke Plant, Great Lakes Steel Corporation, Ecorse, Michigan.

GARRETT BURGESS, *Manager*, Garrett Burgess, Inc., Detroit, Michigan.

S. M. OGLEBY, Hanna Furnace Division, Great Lakes Steel Corporation, Zug Island, Michigan.

L. S. VOIGHT, Hanna Furnace Division, Great Lakes Steel Corporation, Zug Island, Michigan.

L. A. UMANSKY, *Steel Mill Engineer*, Industrial Department, General Electric Company, Schenectady, New York.

L. R. MILBURN, *Electrical Engineer*, Great Lakes Steel Corporation, Ecorse, Michigan.

A. J. F. MACQUEEN: Is there any difference in the method of putting tubes in these high pressure drums?

D. N. MAUGER: Yes, the A.S.M.E. code recognizes two methods of putting tubes in where the thickness of metal in the drum is greater than that required to get a proper bearing for the expanded tube. In one method the tube hole is counterbored from the inside to a larger diameter than the outside diameter of the tube. The depth of the counterbore is such as to leave the depth of the tube seat sufficient for expanding. The tube end projects beyond the tube seat and is flared in the usual way into the counterbored hole. In the other method the counterbore is from the outside and the tube is then flared on the inside of the drum in the usual way. The tube seats, in either method, are grooved to give added tightness and holding power.

W. H. COLLISON: I don't happen to be very familiar with boilers but some years ago an experimental installation of finned tubes was made in the furnace of a still in an oil refinery which gave efficiencies barely equal to plain tubes. A conclusion might be drawn that when the hotter side of a tube used in heat exchange has greater area than the cooler side, there is no gain in heat transfer with increase of the area exposed to the heating gases. What are the applications of the studded tubes? Are they used where the furnace gases circulate around them?

D. N. MAUGER: The studs form a means of holding chrome ore refractory between or on the furnace wall tubes, depending upon whether the tubes are partially studded or fully studded. The studs conduct the heat away from the refractory and into the tube wall. Another use is in furnace slag screens placed across a furnace beyond the point of most active combustion of pulverized coal. Full studs are used on furnace slag screens and entirely covered with chrome ore. This makes the outer surface hotter than a bare water cooled tube so that ash particles adhering to the hot surface stay molten and drop back into the furnace.

GARRETT BURGESS: What is the tensile strength of steel used for high pressure boiler drums?

D. N. MAUGER: Usually 70,000 lb. per sq. in. tensile as against 55,000 some few years ago. The higher tensile strength means thinner drums for the same pressure, joint efficiency and tube ligament efficiency.

S. M. OGELBY: Do you have anything developed in coke oven gas burners for large boilers?

D. N. MAUGER: Yes, but coke oven gas is too valuable today to be considered as a fuel for firing large boilers. Usually, I believe, the steel mills sell it for domestic use in homes and for other purposes where a return is realized for it. Blast furnace gas comes to boilers about half burned giving a high gas weight with low Btu. per pound. Once in a while we hear of mixing a small amount of coke oven gas with blast furnace gas to enrich the latter.

L. S. VOIGT: In present day practice are boiler drums always welded electrically or is acetylene welding used at times?

D. N. MAUGER: Today welded boiler drums are always electrically welded. Acetylene welding is not permitted by the A.S.M.E. code.

GARRETT BURGESS: How are tubes made for use in high pressure boilers?

D. N. MAUGER: The company I represent makes and recommends seamless steel tubes for high pressure boilers. In this process a billet is pierced and rolled out into a seamless tube. The amount of work done on the tube metal refines the grain structure and makes it more homogeneous. We think a seamless tube is better than a welded tube for high pressure boilers, but our friends in Republic Steel Corporation have done a fine job with electric welded tubes which are quite extensively used for the lower pressure boilers but not so extensively for high pressure.

GARRETT BURGESS: What tolerances are allowed on tubes for 900 lb. pressure?

D. N. MAUGER: For seamless tubes up to and including 4 in. nominal outside diameter, the outside diameter may be $\frac{1}{64}$ in. over and $\frac{1}{32}$ in. under, including out-of-roundness. The variation in thickness from that given in the code is zero per cent under and 28 per cent over.

GARRETT BURGESS: How do you sustain your heat at approximately 200,000 Btu. liberation per sq. ft.? I presume that is taken care of by the water walls.

D. N. MAUGER: High Btu. liberation per cu. ft. usually means high furnace temperature which, as you say, dictates furnace walls to absorb sufficient radiant heat to get the temperature of gas leaving the furnace and entering the boiler bank down to a proper degree. The tendency today is to "bury the corpse" of Btu. per cu. ft. heat release as being no real measure of what goes on in the furnace; the real measure is the actual temperature of gas leaving the furnace.

GARRETT BURGESS: What would you consider a tangible unit of measurement to determine the rating of a boiler with the elimination of the Btu.? Would you consider the output in pounds of steam per hour converted to horsepower to represent the proper unit of measurement?

D. N. MAUGER: We used to speak of the rated horsepower of a boiler in terms of 10 sq. ft. of boiler surface. This took no account of the heat absorbed in the superheater. In a modern high pressure, high temperature boiler where the superheater is designed to give 900 to 950 degrees F. total temperature, it may surprise you to know that the superheater absorbs some 27 per cent of all the heat absorbed by the unit and the furnace some 40 per cent.

You will see from this that the old way of determining the per cent rating has become meaningless as, in addition to the heat absorbed by the superheater, a square foot of water wall surface may be absorbing heat three times as fast as a square foot of convection surface in the boiler proper.

While it is possible to take the pounds of steam output, determine the Btu. content and divide this by 33,500 to get the horsepower, it would not mean very much because, as in the above mentioned case, the superheater would account for 27 per cent of the horsepower.

In my own company we talk in terms of pounds of steam output but in our calculations everything is on the basis of Btu. output measured above the Btu. in the feed.

Looking ahead, I believe we will all come to the "Btu. output" or "Btu. absorbed" method of rating boiler units.

MEMBER: What is the highest pressure of modern boiler installations?

D. N. MAUGER: The boiler we are building for American Gas & Electric Company for Twin Branch Station is designed for 2650 lb. per sq. in. The drum shell was a seamless forging, made for us by Midvale, 8¼ in. thick with open ends. The drum heads were hemispherical in shape made by and welded to the shell by our company.

L. A. UMANSKY: What is the average efficiency of high-pressure boilers operating at, say, 1200 lb. per sq. in., 900 degrees F.?

D. N. MAUGER: Eighty-seven to eighty-eight per cent gross.

L. R. MILBURN: Have they got that high pressure, high temperature boiler installed at Delray, Detroit Edison Company, corrected yet? They had trouble with it at one time, burning out tubes at high pressure.

D. N. MAUGER: The trouble you refer to is, I believe, in the superheater. On the first three high pressure high temperature units we had the superheater tubes placed quite close together to take advantage of gas mass flow between the elements.

The stokers at Delray ran the whole depth of the furnace as against the double stokers at Conners Creek. They had some trouble at first in controlling these deep stokers so as to get complete combustion in the furnace which was some 60 ft. high. There was flame at maximum capacity clear through the unit even at the outlet end of the economizer. The ash carried up from the stoker collected in the narrow lanes of the superheater where the flame had the tendency to vitrify it. The resulting plugging of certain lanes unbalanced the gas mass flow through the superheater and overheated certain elements.

While the Delray people have done a lot to improve the operation of the stokers, and have installed telescopic soot blowers to assist in keeping the superheater lanes open, we have, on the two new Delray boilers, opened the lanes in the forward portion of the superheater so that there will be 4½ in. between the tubes instead of .8 in.

The boiler companies have stepped into some pretty tough problems to lick in going to high pressures and temperatures but at the present time we believe we have them pretty well licked. While we have learned a lot and believe we have applied what we have learned to

(*Please turn to page 59*)

Steel Mill Gear Tooth WEAR and FAILURE

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▲ THE subject of gear tooth wear and failure is a sizable one, consisting of several important parts, such as gear design, rigidity of mounting, precision in manufacture, maintenance, lubrication and material. Each one is capable of furnishing sufficient subject matter for a lengthy discussion. Since it is beyond the scope of this paper to discuss all of these, the subject of basic gear design and lubrication generally will be omitted or assumed for the present to be satisfactory. The remaining parts of the subject will be discussed from a practical viewpoint, endeavoring to point out ways and means of obtaining the maximum service from equipment of current design, occasional mention being made of modifications that are believed desirable from a maintenance point of view and not too objectionable to the gear manufacturer.

The first and most logical step towards accomplishing any end is to take advantage of all available data pertaining to the subject. The automotive gears afford a good example and have, because of their high production and adaptibility to volume destructive testing, been the source of many gear refinements, both in design and manufacturing methods. Much of this knowledge can be applied to steel mill gears and their maintenance. For this reason occasional reference will be made to the technique employed by the automotive gear manufacturers.

For ease of discussion, gear tooth wear and failure should be divided into five separate types, each being a distinct form of gear tooth destruction. These are:

1. Abrasion or common wear
2. Pitting
3. Scoring
4. Surface flow
5. Tooth breakage.

ABRASION OF GEAR TEETH

Abrasion is the most desirable form of gear tooth destruction and when it is at a minimum indicates that the correct balance has been obtained between unit pressure, material and lubrication. Ordinary abrasion is most common on hard surface gears, because those put in service at machineable hardness, when subjected to abuse, generally exhibit some form of surface flow, scoring or pitting, in addition to abrasion. Carburized and quenched gears probably give the greatest resistance to abrasion and plain carbon, oil hardening type, when poorly quenched, probably gives the least. A few common causes of excessive abrasion on hard gears are overloading of tooth surfaces, poor lubrication, foreign or abrasive matter in lubricant or passing through gear mesh, rough tooth surfaces and poor heat treating.

PITTING OF GEAR TEETH

Pitting of gear teeth has been the source of several investigations and has engaged the minds of many of our best gear men, but still remains a subject of controversy. While we may not understand the behavior of certain phases of pitting, it is known that pitting on gear teeth is most pronounced at the pitch line, where sliding action is at a minimum and compressive load or rolling action is greatest. Under normal load, pitting is seldom encountered at the top or bottom of gear teeth or at any point on worm or hypoid gears of high helical angles. This is one way of saying that pitting is the result of relatively high unit pressures, accompanied by maximum rolling action; that pitting is diminished as rolling action gives way to sliding action, even though unit pressures may not be appreciably reduced. This fact was proven several years ago when helical gears replaced spur gears in the automobile transmission in which pitting was a source of considerable trouble. Many of these designs did not permit wider gear faces, therefore, thrust loads resulting from helix angles were added to tangential loads, giving no reduction in tooth pressures per inch of face, but pitting was greatly relieved by the change.

This lesson from the automotive gears can be applied to reduce pitting on industrial gears because it proved that slippage of the profiles reduces the tendency to pit and rolling or compressive loads increase it. By making use of this principle, it is believed that the designs now produced by the modern gear engineer can be manufactured with sufficient accuracy and from material of such physical properties that pitting can in a great majority of cases be eliminated.

J. H. JONES

Pitting of gear teeth may be eliminated or reduced by producing gears of maximum hardness and physical properties consistent with their method of manufacture and service requirements; by taking advantage of the maximum area of active profile; and by so modifying the tooth form that new gears go into service with a slightly split or hollow tooth contact at the pitch line instead of a narrow concentrated band at this location, thus avoiding maximum initial load on the portion of tooth where rolling action or compressive load and tendency to pit is greatest.

Initial contact should be well distributed over the remainder of the profile, both above and below pitch line where tendency to pit is at the minimum. New gears should go into service with top of teeth relieved or topped off so as to avoid scraping off the lubricant during arc of approach and thereby allowing metal to metal contact at the corners or tops of teeth. This topping off should be slight because it reduces the theoretical arc of contact and should be a very low angle, blending in gently to addendum profile. A 45 degree chamfer is little better than no top-off at all because the 45 degree corner will scrape off an oil film almost as thoroughly as one of 85 or 90 degrees.

Development of a hollow or split bearing, as referred to, should be done with discretion because an extreme in this direction is as bad as a narrow contact at the pitch line which must pit out before the rest of profile can come into engagement. An extremely narrow band at top and bottom of tooth amounts to the same as top interference of both members and would undoubtedly result in scoring at these points. Actual experience has proven that new mill pinions of about 200–240 Brinell, having a slightly hollow contact at pitch line with the other qualities just mentioned, run in perfectly with no scoring at top or bottom of teeth. Surface flow at these points soon brought the entire profile into contact and permitted the area where pitting is most likely to occur to cold work and pick up its load gradually under the favorable condition of being the last portion of tooth to come into engagement, after which the surface loads were so well distributed that no pitting developed. Other pinions of the same hardness and running under similar conditions, but having an initial tooth contact along a narrow band at pitch line pitted badly within the first three to five months of service. These pinions were in both cases of machineable hardness, but examples can be cited where a similar modification has been beneficial in terms of reducing the tendency to pit on hardened gears of 50–55 Rockwell C.

It is agreed that either large or small gears can be made to match or show bearing contact across the full face width much easier when the bearing is restricted to a narrow contact at pitch line than when distributed over the whole active tooth profile. It must also be agreed that when the theoretical contact area is reduced 50 or 75 per cent and concentrated at pitch line, the unit pressure is increased accordingly and tendency to pit is still further increased because of the positioning of bearing at point of greatest rolling action as already explained. This is not a new theory on pitting. Instead, it is so old and elementary that it is often overlooked.

It is not believed that pitting is affected in any way through the use of extreme pressure lubricant. However, certain investigations have indicated that the more viscous or dry lubricants may retard the tendency to pit because of their lower hydraulic action on microscopic surface cracks, which apparently constitutes the initial stages of pitting, but because of their low cooling qualities, the use of these lubricants is limited to gear sets operated at relatively low speeds or light loads.

SCORING OF GEAR TEETH

In regard to scoring it should be mentioned that the use of extreme pressure lubricants is recommended in running in new gears as an insurance against scoring of the surfaces above and below the pitch line. This is especially true of gears going into service at machineable hardness, or those having a wide contact from top to bottom of tooth, or in the case of the slightly hollow bearing at pitch line previously described.

On gears of machineable hardness, the physical properties of the gear blanks are a factor used in calculating the load carrying capacity, and it goes without saying that the higher these properties are, the higher the surface endurance and beam strength of the gear teeth will be. Until recently, it has been erroneously assumed that to facilitate machining gear blanks, they should have a maximum Brinell hardness of about 207, which corresponds to 98,000 lb. per sq. in. tensile strength. It is now known that after the proper heat treating of blanks, a Brinell hardness of 305 will machine almost as well and probably give a better tooth finish. This hardness corresponds to 139,000 lb. per sq. in. tensile strength instead of 98,000 lb.—an increase of 40 per cent. This hardness and structure is obtained by the use of a sufficiently high alloy and a regular slow anneal, followed by reheating and normalizing or quenching, depending on the analysis and size of part. It is then drawn back to the hardness desired. This treatment results in a uniform sorbitic structure instead of the less uniform and often poor machining pearlitic structure obtained from the former single treatment.

The only advantage of the softer gear just mentioned

is found when gears run badly out of alignment. The softer gear will, due to its higher plasticity, deform and re-distribute the tooth contact more rapidly than a harder one. With the proper maintenance this characteristic cannot be considered an advantage over the stronger and normally longer lived gear. A further increase in physical properties and resistance to scoring and pitting may be had over the 305 Brinell blank on gears of such size and design as permit heat treating after machining. This is accomplished by quenching and drawing back to give the degree of hardness and ductility consistent with service requirements. Carburizing, quenching and drawing at a low temperature will give still further tooth life, providing the installation is sufficiently rigid to maintain a good area of tooth contact.

TOOTH BREAKAGE

It has already been mentioned that as gear teeth are made harder and the service life expectancy increases, the matter of alignment and initial tooth contact becomes more and more important. This requirement must be met or service life of the harder gear may because of tooth breakage be less than that of the softer one. Very good examples of this have been noted in cases where soft gears were replaced by hardened ones. Little attention was given to the initial tooth contact on the soft gears because if the bearing contacts were concentrated or the gears were poorly matched, a short initial run would, through plastic flow and pitting, distribute tooth contact over a reasonable area.

The hard gears of 50–55 Rockwell C with the most ordinary heat treating should have greater strength than the softer one, but in a case observed the hardened gears had an initial tooth contact covering slightly more than one-half of face width on a few teeth. This might not have caused failure on the softer gear, but because the harder surfaces did not deform and unload the contact area on these few teeth, they broke out, giving a service far short of that received from the softer gear. This reference is in no way intended to discourage the use of hard gears wherever practical, but is further proof that anything done to increase the resistance to wear, pitting or breakage of gear teeth must be accompanied by a good initial tooth contact and such contacts must be maintained by reasonable, permanent and rigid gear mounting.

One other common cause of teeth breaking out prematurely on hard gears is notch effect, meaning stress concentration caused from a tool mark, scratch, sharp corner, unnecessary undercut or abrupt change in section. We know that at the root of a gear tooth the section changes abruptly and when a gear is quenched to harden it, stresses are set up at the roots of the teeth, which on experiments quenched in iced brine broke teeth completely off. However, in regular practice these stresses are much lower, but the point is they maintain to some degree in all quenched gears and if the gears have a square corner, deep tool marks or excessive undercut at the root instead of a fillet, it is only further weakening the tooth at the point where it is most highly stressed in service. Generally speaking, the harder the part, the more sensitive it is to notch effect. The automobile shops have long been aware of this hazard and guard against it carefully, but not unlike the manufacturers of steel mill gears, still permit it to take an annual toll in avoidable failures. This is one defect so obvious that it should not be tolerated in any degree.

In regard to bevel gears, the fundamental requirements, such as physical properties of material, manufacturing standards and maintenance, vary but little from spur or helical gears. Bevel gears as a whole are more sensitive to deflection and mis-alignment and due to their mounting and complexity of operating forces demand more study from a maintenance angle than the gears mounted on parallel axes. This is doubly true in the case of spiral bevels or hypoids.

In order to realize the maximum service from bevel gears, such as power takeoff and mill drives, certain means for adjustment are desirable. Adjustments for moving the pinion along its axis are generally provided, but means for moving it in a vertical direction and controlling backlash are just as important, but not always available. Such adjustments would greatly facilitate economic maintenance because a set of gears which appear perfect when rolled on correct centers under light loads may, due to deflection, when operated under full loads, show an unsatisfactory tooth contact.

A combination of the adjustments mentioned could be used to compensate for deflection or slight misalignment of the setup. In the event a gear set should be allowed to run off center due to excessive bearing wear, when re-aligned often gives only a spot tooth contact which is generally at the small end of tooth and may result in breaking the tooth out instead of running in. If vertical and backlash adjustments were possible, such gears could be brought back to center in two or three steps, thus reducing the danger of breaking teeth out of an otherwise serviceable gear.

Operating loads cause the following deflections on a set of straight bevel gears. The pinion moves off center in the vertical direction due to tangential force; it also moves back along its axis as a result of pitch angle. The two gears separate and increase their backlash as a result of the pressure angle. Each of these three, shift bearing contact toward the heel or large end of tooth. Loose shaft bearings add to these movements. In addition, the pinion movement along its axis shifts the contact toward top of gear tooth and deeper in pinion tooth. The shifting of contact to some degree, depending on rigidity of mounting and load applied, must be expected and takes place just as surely as the gears are loaded and rotated. Therefore, it seems that some means of compensating for such movements would be desirable and would facilitate the correct mounting of new gears and keeping them properly adjusted in service.

There is little doubt that a careful study of the factors influencing the movement of tooth contacts, coupled with a sincere application of such knowledge in maintenance would save the average steel mill thousands of dollars annually in gear replacement to say nothing of the expensive, unexpected breakdowns that could be avoided. The gear manufacturer can increase the life of new or replacement gears by giving more attention to so-called minor details, such as initial tooth contact, gear finish, root fillets, heat treatment, and stronger blanks for all gears, especially those going into service at machineable hardness. These and many other points hold great potentialities for improvement, all of which will be needed to meet the ever increasing demand for higher speeds and loads at lower operating costs.

DISCUSSION

PRESENTED BY

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J. H. JONES, Metallurgical Department, Republic Steel Corporation, Massillon, Ohio.

L. F. COFFIN: It would be well if more engineers fully realized the significance of some of the basic facts of gear wear and failure as presented by the author. It is felt that abrasion of gear teeth can be materially reduced on many small and moderate sized installations by more frequent use of oil sprays at the meshing point of gear teeth. This practice is generally followed on large drives, but smaller drives, such as for high speed precision shears for tin plate cut-up, could well follow the same liberal use of a flood of oil to take away heat and abraded material.

The analysis of the causes of pitting as given by the author appears quite logical. On one large herringbone reduction drive for a 160 in., three-high plate mill it was found that teeth were pitted considerably, gear coating being the lubricant.

Upon re-erecting this drive at another site, re-aligning the drive, and reversing the direction of rotation and increasing the load per inch of tooth face due to change in mill pinion ratio, it was decided to use 550 second viscosity oil as the lubricant. It was freely predicted by some that teeth would pit so badly as to cause a failure. Pitting did occur and spread rapidly until a full tooth bearing had established itself, after which additional pitting ceased and has never reappeared. This case supports the author's contention, and indicates further that lapping in of gear teeth on any important drive before starting operation is a much to be desired and fought for objective.

The author's comments on the advisability of relieving the top of tooth so as to avoid scraping lubricant from the approaching tooth are well taken. This practice should be followed by manufacturers and should be insisted upon by purchasers. Frequently this has to be done in the field to prevent just this occurrence.

W. P. SCHMITTER: I have read Mr. Jones' paper with much interest. The matter of gear hardness has engaged the attention of gear people of late. They have not all come up with the same answer. The fact that high hardnesses have been satisfactorily adopted in the automotive field does by no means indicate that they may be used for rolling mills. The conditions under which steel mill gearing must operate are far more severe than those encountered in either truck or pleasure car service. The salient differences appear in Table A.

We must agree with Mr. Jones that, other things being equal, surface durability will increase with hardness. Up to the limit of machineability index errors and surface contacts can be attained at approximately their theoretical optimum. Any hardness beyond that point can be had only with the sacrifice of accuracy. Pitting takes place approximately when the sub-surface shear stresses reach the fatigue strength of the material, but there is no good in increasing one if the other steps up proportionally. Moreover, concentrations arising from

TABLE A

Comparison of Gear Requirements

Automotive Duty	Steel Mill Duty
1. Short life—total of not more than 3000 hr. at reduced load on rear axle and probably not 30 hr. on transmission gear.	1. Long life requirement—total of from 25,000 to 100,000 hr.
2. No shock loading—impact properties secondary.	2. High resistance to shock loads is a primary consideration.
3. Tooth loadings do not increase rapidly with index error because of extremely elastic system (long propeller shaft, rubber tires, springs and floating power). This makes it practical to harden after cutting teeth.	3. Rigid system (large masses and heavy shafts) requires accuracy in gear tooth spacing in order to keep dynamic loadings at safe values.
4. Localized tooth bearings employed. Narrow faces with crowned teeth on transmission elements and rocking chair bearing on bevels. Distortions from fire do not lead to corner loading or material loss of contact.	4. Rolling mill gears of wide faces and multiple helical contacts. Any distortion reduces contact area considerably.
5. Small gear masses, simple shapes, and high production all make for accurate control of heat-treating processes. Much of the distortion can be removed by special lapping equipment.	5. Large mass, irregular shapes and individual manufacture increase heat-treating problems. Desirable not to harden after cutting.
6. Nature of automotive gear transmissions such that errors in mounting are rare. Even the natural deflections of teeth and shafts may be allowed for in machining case.	6. Possibility of misalignments from settling foundations and extreme overloads on wide face gears requires that they have good self-corrective properties.
7. Large quantities made from a single design permit extensive field testing. Gears proportioned by cut and try method.	7. Theoretical estimates of loading and capacities must be relied on.
8. If occasional gear goes bad, it inconveniences one car owner until nearest garage can replace with stock item.	8. Failure extremely costly and may involve shutting down an entire mill for weeks.

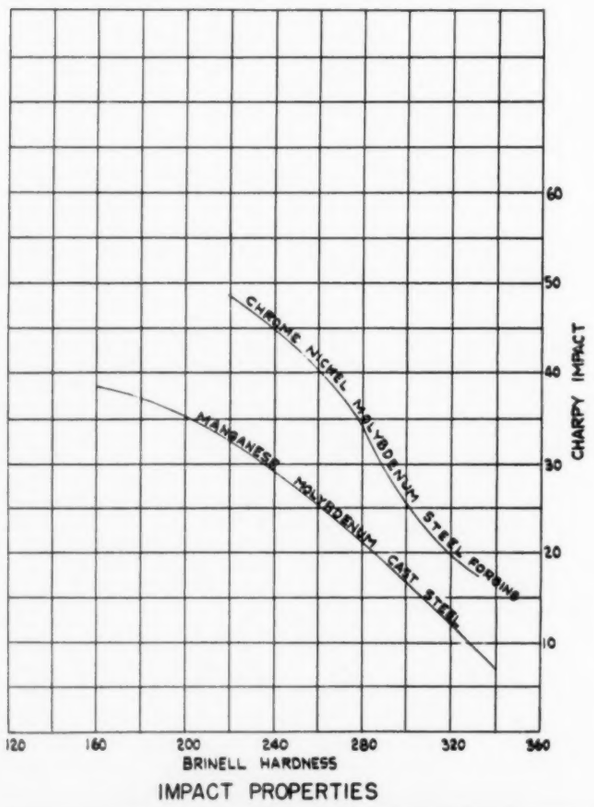
heat treatment after cutting frequently produce localized stresses that lead to tooth breakage.

Even if we had available a process by which we could obtain the higher hardnesses without distortions, we would still have to accept materially lower shock resisting characteristics. Figure 1 shows how the impact properties decrease with increased hardness. Mr. Jones has suggested pinions heat-treated before cutting to approximately 300 Brinell. We find the range of 235–270 Brinell as being the most satisfactory all around. The metallurgical treatment he prescribes is the one we regularly use. While we agree on the superiority of the sorbitic structure, we have not found it as freely machining as the pearlitic.

The hazards involved in the use of high hardnesses have caused us to concentrate our efforts toward improved surface durability upon other factors. We found that the tooth bearings could be materially increased thus reducing contact stresses. Figure 2 shows the relative pitting obtained with the old standard and the new tooth forms during a test involving identical materials, loadings and lubrication.

Mr. Jones does not believe that pitting is affected in any way through the use of extreme pressure lubricants. Our experience does not permit us to support this contention. On the contrary we find that extreme pressure compounds, particularly of the leaded soap type, may materially increase the load carrying capacity of a set of gears. We have been able to arrest pitting completely by a mere change from a straight mineral oil to a leaded

FIGURE 1



IMPACT PROPERTIES

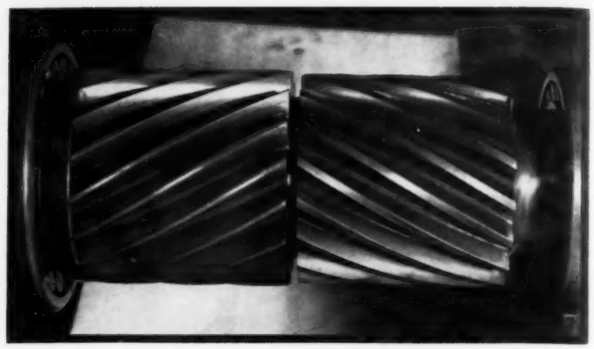


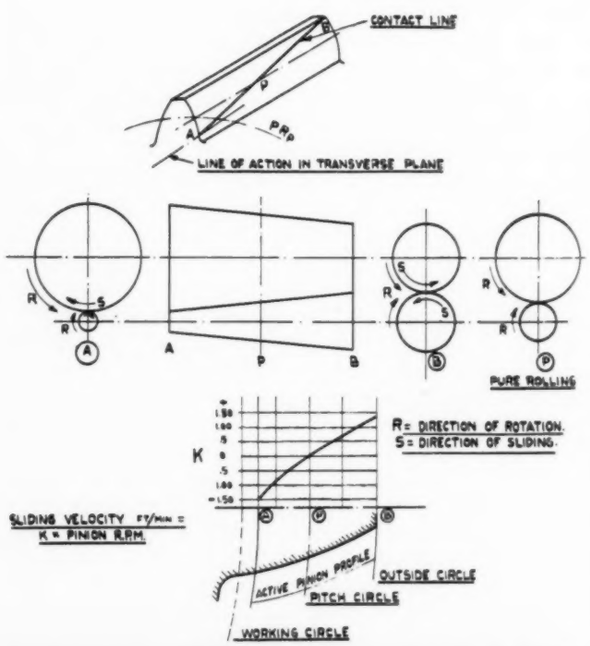
FIGURE 2

soap compound and not necessarily to one of higher viscosity. Extreme pressure lubricants are instrumental in supporting the load even though we do not understand the precise manner in which they function.

As Mr. Jones has indicated, sliding appears to perform a useful function in resisting pitting. The experiments conducted in Japan by Toshio Nishihara, on loaded rollers in pressure contact and arranged to operate with varying degrees of sliding, demonstrated that the greatest tendency toward pitting occurred at a slip of about 20 per cent. At a sufficiently higher ratio of slip the development of pits could hardly be observed.

In thick film lubrication the load carrying capacity of a lubricant depends among other things upon its effective viscosity and the velocity of sliding. The situation with regard to the complicated conditions of repetitive formation and breakdown of film under widely varying proportions of rolling and sliding such

FIGURE 3



as exist in gear action is, as yet, unexplained. We are probably safe in assuming that high relative sliding toward the extremities of the tooth surfaces leads to the development of a film of tangible thickness. This is of no particular significance with regard to spur gears as as the entire load is momentarily supported solely at the pitch line. In helical gear action sliding occurs at one portion of the tooth simultaneously with pure rolling at another (see Figure 3). A measurable film thickness toward the tip may relieve the pressure at the pitch line. Moreover, the elimination of the pitch line region by pitting does not impair the material at other portions. Fundamental research on gear lubrication will some day disclose the reasons for the leaded soap compounds' greater resistance to pitting. It may be associated with its high film strength, or an inherent ability to rapidly build up a film under the difficult conditions described, or possibly a capacity to maintain viscosity under pressure will be found to be the explanation.

Our experience with modern lead soap compounds has lead us to develop a series of rolling mill drives incorporating a simple self-contained splash system intended for the exclusive use of such compounds.

Mr. Jones reports some interesting results with use of gears having hollow tooth profiles. Pitting in spur gears first manifests itself just below the pitch line where the profile is sensitive, relative directions of rolling and sliding are favorable to its formation, and single tooth contact begins. The oil film probably collapses just as sliding approaches a minimum. Loss of active profile is much more serious than in helical gears. Pitch line pitting is not a matter of great concern in the case of the latter. When it begins to spread progressively to other portions of the tooth, it generally heralds short life. The suggestion of Mr. Jones is worth careful investigation.

S. L. CRAWSHAW: Mr. Jones is to be congratulated for the manner in whigh the subject has been approached. It is rather difficult to eliminate the factors of basic gear design and lubrication from any general discussion of gear tooth wear and failure when such terms as precision in manufacture and maintenance are included. My remarks, however, will be directed to the paper as presented.

Mr. Jones calls attention to the comparison between automotive and steel mill practices. It has been our experience that these two fields are so far apart in duty requirements and life expectancy that entirely different design principles must be set up. The average life of an automobile would be used up in several months of continuous industrial service. The automobile transmission seldom is called on to develop its peak load capacity; whereas, many industrial applications in the steel mill are worked up to a small margin of safety continuously.

The destructive testing program of most automotive builders has been centered around failure by fatigue breakage and due to the high production rate of duplicate units, they are able to test complete structures, thus evaluating such factors as size, mounting, temperatures, deflection and lubricants. Each steel mill application presents a new set of operating conditions, making it necessary to compromise all factors to suit the economics of the job.

The types of gear tooth wear and failure are well chosen; one might suggest such additional terms as spalling, which appears to be an aggravated form of pitting, but is generally a result of resistance to surface flow causing large flakes of metal to be dislodged. Seizing is another term used to describe a form of surface flow failure wherein very high localized temperatures develop a pressure weld.

Abrasion is referred to as the most desirable form of gear tooth destruction when it is held to a minimum. Gear teeth classed under this method of wear can be distinguished by their fine grooving or scratches in the direction of sliding. Normal wear is a mild form of abrasion developed from the recirculation of fine particles which have been polished from the contacting surfaces. Abrasion can often be reduced by filtering the oil or using a heavier bodied oil which will carry the foreign matter through the mesh without its contacting the tooth surface.

We agree heartily with Mr. Jones' remark that pitting of gear teeth remains a subject of controversy. Most experimenters agree that the pitting phenomenon is a result of high contact stresses inducing fatigue failure. Our observations lead us to question the statement that "pitting on gear teeth is most pronounced at the pitch line." Seldom, if ever, have we seen pitting extending above the pitch line and in most cases it has been most pronounced below, probably due to the direction of sliding in this zone being more favorable to pit formations.

With regard to pitting of the spiral type of bevel gearing Mr. Almen of the General Motors Corporation, in his A.G.M.A. address, "Factors Influencing the Durability of Spiral Bevel Gears for Automobiles," pointed out that this type gear starts to pit at a point just below the theoretical pitch line of the pinion near the large end of the teeth and progresses to the small end. He also stated that pitting was not a factor in passenger auto gearing due to the life expectancy being reached before pitting developed to the point where it would be detrimental.

Mr. Jones implies that in helical gears a sliding action is introduced which is not present in spur gears. It is true that there is not rolling at all points on the pitch line simultaneously, but the situation at any particular point on the pitch line of a helical tooth seems to us to be kinematically equivalent to that of a point in the pitch line of a spur tooth. The improvement in load carrying capacity of helical teeth over spur teeth may be more logically due to the reduction in dynamic loads, also, the minimum length of contact line is increased in helicals.

We are very much interested in Mr. Jones' suggestion of modifying the tooth form to reduce the pitting hazard by providing a hollow tooth contact at the pitch line. We would like more information on the amount the tooth forms were modified in those cases which have been tried out. Our company's records show that some such method was experimented with some years ago by scraping a groove in the gear profile at the running pitch line. Plastic flow of the metal did fill up the groove in some spots and the amount of pitting was reduced. We must remember, however, that the operating pitch line may vary in physical location on the tooth due to spread center distances, deflection or misalignment. Furthermore, the contact stress is usually greatest near the pitch line at the point where the change in contact conditions occurs. These considerations may preclude

the possibility of predetermining the hollowing out of the teeth. Such modifications will not reduce the tooth loading and may transfer the point of greatest pressure to some other point.

Contrary to Mr. Jones' statement, we have found extreme pressure lubricants to be helpful in cases of pitting—particularly those of the incipient nature.

Scored gearing may appear to have been subject to abrasive action; however, it is largely due to poor contact conditions, rough surfaces or soft spots. These latter conditions develop "pressure welding." Scoring is not so prevalent in high hardness gearing or in sets where the pinion hardness is considerably higher than the gear.

Mr. Jones does well to emphasize the importance of proper mounting for gears of high hardness. This includes both the type of mounting and assurance of good alignment. These factors are always desirable to get the most out of any gear set—soft or hard—but a type of mounting that might be suitable for lightly loaded gears would not be suitable for heavily loaded hard gears because of shaft deflections. We might call to your attention the fact that size alone determines the deflection rate since the modulus of elasticity does not change appreciably with alloys or heat treatment. Notch effect, or a residual stressing set up in heat treatment, can be minimized by proper tempering.

In conclusion, Mr. Jones suggests that the gear manufacturer can increase the life of new or replacement gears by giving more attention to such items as initial tooth contact, gear finish, root fillets, heat treatment, etc. Such research work is being actively carried on in the A.G.M.A. group. Continuous load tests of rollers and gears are being made to study the effect of materials, hardness combinations and tooth contact in order to improve existing standards and formulae.

Due to the wide variety of applications in which gears are used in modern industry, it will never be possible to develop the final answers in the laboratory to the extent that it is in the automotive field. The continued cooperation of steel mill operators is a vital factor in this development program and it is hoped that we, as gear manufacturers, can call on you men for guidance in the future, as we have in the past.

F. L. GRAY: In the early days of the extreme pressure lubricant we put in a new pinion set which had been designed to take the load with a good safety factor, but as an added precaution we also used an extreme pressure lubricant. At the end of 80,000 tons, an average monthly production, we found pitting on these pinions.

F. J. THOMAS: I would like to add something to the discussion. During the past few years Mr. Jones has been investigating gear conditions in a number of our plants and I have followed these with particular interest. In one plant some very heavy pitting had developed on a set of double helical mill pinions of considerable size. Mr. Jones' observations led us to believe that the pitting was caused by poor tooth form and irregular tooth contacts when the pinions were meshed. These conditions existed in the new pinions as supplied by the manufacturer. As a result, when the pinions were put in service, under load, their only contact was along the pitch line (or slightly below the pitch line, possibly), and only at irregular intervals along the pitch line. This gave irregular line contacts at approximately the center of each tooth. Pitting started at these points and spread axially along the teeth and also crept above and below the pitch line, this being more pronounced at some points than at others. Finally, the pitting existed over the entire length of each tooth and for small irregular distances above and below the pitch line. This, while unsightly, brought most of the tooth areas into contact and reduced unit loading.

Shortly after, it was decided to increase the loads taken by the mill stand driven through these pinions by approximately 25 per cent. Electrical changes were made to accomplish this and it was decided to have a spare set of pinions made, to be installed when the other necessary changes were made, because there was some question as to the behavior of the existing set under the increased load. I should mention, at this point, that these pinions are mounted in roller bearings which hold them rigidly in position, and do not permit them to change their meshing point appreciably.

In line with Mr. Jones' suggestions the manufacturer gave very thorough attention to the machining of these new pinions and they were inspected several times by our people before they were completed, and some suggestions made were carried out. The final result was that these pinions which had been rolled together in one position, and so marked for installation, had been worked on until the teeth made complete contact from close to the tip to very near the root of each tooth and from the apex to the end of each helix. Practically all of the available tooth surfaces were in contact. These new and carefully made pinions, of the same size and material as their predecessors, but with a sharper helix angle, were subsequently put in service in the same housings but under 25 per cent greater load conditions.

The lubricant originally fed to this pinion stand from a circulating system had been of the so-called "extreme pressure" type with a rating of 35 lb. on a testing machine. The extreme pressure qualities of this lubricant had had no effect, apparently, in preventing the pitting that occurred. It is my understanding that pitting of gears lubricated by extreme pressure compounds, lead soap or otherwise, is not unusual.

When the new set of pinions were put into service under the increased load conditions, they were watched for signs of pitting to develop. No change was made in the lubricant used. After having been in service a greater length of time and under higher tonnage operations than the original set, the teeth appeared to be in perfect condition and no pitting was developing.

This, naturally, is only one experience. It appears to indicate, however, that if the loading can be spread over the tooth areas originally designed to take that load, and these contacts are maintained by rigid roller bearing mountings, and an adequate lubricant is properly supplied, pitting can be greatly reduced and, to a great extent, eliminated.

One further point. We seem to have found in a number of cases where pitch line pitting occurs, that if it proceeds far enough to bring enough tooth surfaces into contact to distribute the load to a point where abnormal unit pressures do not occur, the pitting will slow up and eventually stop. After this has occurred the pinions will probably continue to wear normally, unless total loads become too great, and may give exceptionally long

service. Many of the things Mr. Jones has brought out in his paper appear to be borne out by investigation made in our various plants.

F. L. GRAY: We have not gone into the use of extreme pressure lubricants in our plant as some of the other steel plants have. We have felt that we would rather reserve the extreme pressure lubricant for the over-loaded condition that develops later. We have taken that stand against the advice of the late Mr. Percy Day. I think Mr. Schmitter might remember this. In one case we had a worm that was designed to take the heavy slabs we were rolling for the Boulder Dam job. It was on a shear lifting table. After completing that order, we dropped down to a small light weight slab. This worm and motor were lifting an extremely heavy counterweight. The electrical department found an over-loaded condition on their motor. This timely inspection possibly prevented destruction of the gear teeth.

There is no question that we were getting a breakdown of our oil film. We put an extreme pressure lubricant on the worm and gear, which gave us an oil film and cut down the load on the motor.

Mr. Schmitter spoke of designing gears with the consideration of an extreme pressure lubricant. I would like to hear something more about that.

W. P. SCHMITTER: It is quite conceivable that the same gear that is lubricated by a lead soap compound can be lubricated by a mineral oil. However, that is not always the case. Frequently a gear of smaller proportion, lubricated with a lead soap compound will show equal or better life than a gear of equal hardness and quality lubricated by straight mineral oil.

But that doesn't necessarily mean that in the designing of a gear for lead soap compound the proportions are altered from what they would be, had the design been initiated with the idea of using straight run mineral oil.

We recognize this fundamental distinction, however, that the latent extreme pressure properties which may be drawn upon only in the case of unforeseen overloads are available without loss of any of the desirable gear characteristics obtained with oils suitable only for normal pressures. The leaded soap compound lends itself peculiarly well to an extremely simple splash lubricated system in which the amount of lubricant reaching the gear is controlled by a valve pan arrangement. A great many of you are familiar with that design and have used it with entire success.

Along with that is incorporated a cooling means for keeping the viscosity of the lubricating compound at the working surfaces at a value judged to be most suitable for the particular job in hand. It is one thing to have a low viscosity in the oil pump or in your circulating system but it is another thing to have the viscosity most effective for the mesh simultaneously with that best adapted to the bearings.

These, briefly, are the objectives we have striven for in our rolling mill designs.

R. M. GORDON: I would like to ask Mr. Schmitter whether he has checked the leaded compound after it has been in service for extreme pressure characteristics —whether or not it has deteriorated, and whether or not that deterioration has impaired the efficiency?

W. P. SCHMITTER: No, there appears to be no deterioration. We in our own plant, some fifteen years ago, applied an asphalt lubricating compound to a newly installed 2000 hp. two-pinion gear driven Diesel engine generator drive. The load increased progressively for the next eight or nine years, by which time rather severe pitting had taken place, causing not a little concern. About that time we changed to a leaded soap compound which arrested the pitting. We left this in the unit for seven years, taking samples frequently, and it was only within the last year or so that we renewed the lubricant. Now in none of those tests had the lubricant lost any of its effectiveness insofar as we could discern.

R. M. GORDON: Did you run extreme pressure load tests on it?

W. P. SCHMITTER: We didn't run it on the testing machine or anything of that kind.

J. W. KIGHT: I would like to elaborate on two points that have been mentioned in this paper.

First is the matter of pitting, which I believe is frequently confused with spalling. It has been borne out in these papers that gear failure from pitting is due to the failure of the lubricant to prevent metal to metal contact on the working surface of the gear tooth. Pits are usually small smooth holes which first occur on or near the pitch line. Spalls are, I believe, usually larger and first occur well above or below the pitch line. Spalling is due to failure of the metal of which the gear is composed due to the formation of fatigue cracks which eventually loosen small pieces of metal sufficiently to permit them to fall out of the tooth face. The cause of the metal failure is apparently insufficient elasticity.

The second point is the fact that there are several varieties of extreme pressure lubricants commonly used in steel plants. One of them is similar in nearly all characteristics except load carrying properties to a straight mineral circulating oil. The other is the black type which usually contains a lead soap for its load carrying agent. This black type has a characteristic not found in a straight mineral oil or in the first type mentioned, and that is tackiness.

This tackiness can best be illustrated by taking a straight mineral oil and both types of extreme pressure lubricants all having the same viscosity, and applying them to a metal surface. It will be found that the black type extreme pressure lubricant forms a thicker film, and a film that resists being squeezed from the surface to a greater degree than either the straight mineral oil or the first type of extreme pressure lubricant mentioned. It appears to me that this tackiness of the black type of extreme pressure lubricant plays a more important part in the lubrication of large industrial gears than is generally recognized since it undoubtedly acts materially in the cushioning of shock loads. This factor in my opinion merits further investigation.

F. L. GRAY: I think that point should be very well taken. I have talked to gear manufacturers and they will condemn an extreme pressure lubricant due to the corrosive action. That may have been true in the past. The oil companies are getting out a better product and I do not believe that our leaded products today have that corrosive fault.

J. W. KIGHT: I didn't mean to imply corrosion. The difference is actually in the tackiness or body.

J. H. JONES: Mr. Coffin cites a typical example in which a gear set developed pitting that spread rapidly until a full tooth contact was established and then it ceased, there having been no change in lubricant. It is reasonable to suspect that with the correct initial tooth contact, pitting would not have started on these gears; also, that should Mr. Coffin have changed to a different type lubricant when pitting was at its worst, he could have reasonably credited the arrest of pitting to the change in lubricant.

It is a proven fact that extreme pressure lubricant increases resistance to scoring or seizing and because of its tendency to reduce surface friction, sub-surface shear stress and operating temperatures. It is entirely possible that it may retard the formation of incipient surface cracks, which later develop into pits, as Mr. Crawshaw has found extreme pressure lubricants helpful in cases of incipient pitting, and Mr. Schmitter states that they have been able to arrest pitting completely by changing from a straight mineral to a lead soap lubricant. In the latter case, I am inclined to wonder whether the pitting cycle was completed and a satisfactory contact established as reported by Mr. Coffin, or whether the lubricant actually arrested the pitting.

In our experience, extreme pressure lubricant has not prevented pitting and to what extent it may have retarded it, we cannot determine. However, we do know from experience, that if we are to avoid or keep pitting to a minimum on heavily loaded gear sets, such as mill pinions—we must aid the extreme pressure lubricant by providing the maximum initial tooth contacts.

Mr. Schmitter's remarks are well taken on the probable difficulties of quench hardening large gears after finish cutting. It is true that higher hardness obtained at the expense of over-all precision would be undesirable and would be contrary to my suggestion to "produce gears of maximum hardness and physical properties consistent with their method of manufacture and service requirement, taking advantage of the maximum area of active profile." This latter requirement could not be met easily on large gears when hard and badly distorted. therefore, we can only move up the hardness scale as material, manufacturing methods and our knowledge of heat treating permit.

It is not believed that we have reached the point where loss of impact properties or machining difficulties prevent further progress along this line. Mr. Schmitter's reference to the new tooth form is of interest and apparently indicates a step forward. The remarks of Messrs. Schmitter, Kight, Gordon and Gray, relative to the function of various extreme pressure lubricants are timely, and touch on a subject holding much interest for all of us.

Mr. Crawshaw adds spalling and seizing to our list of gear tooth surface failures, and I agree with his explanations. Seizing is probably the most vicious of all tooth surface failures and can destroy the entire contact surface in a few minutes.

The statement that notch effect can be minimized by proper tempering is true, and parallels my statement that the harder the part, the more sensitive it is to notch effect. We should remember that on parts of relatively high hardness, the amount of tempering is limited and on such parts, the use of fillets instead of sharp corners still further reduces the notch and its effect.

I believe Mr. Crawshaw has correctly described spalling as being the result of resistance to surface flow, causing flakes of metal to be dislodged. Seizing is a vicious type of surface welding and pitting is probably fatigue failure of the surface caused by repeated loading in compression. Dr. Stewart Way has shown that pitting begins with microscopic cracks in a surface layer thinner than .001 in., which by fatigue progress to some depth and in a direction opposite the approaching contact—progress is accelerated by the hydraulic action of trapped lubricant until the fracture parallels the contact surface and finally progresses to the surface, thus dislodging a slug from the base metal. This work was done on loaded rolls but is the most logical explanation of pitting on gear teeth that I have seen. Another interesting point reported by Dr. Way was that when rolls were run with no lubricant at all, pitting did not develop.

From the foregoing discussion, it might be asked why dwell on pitting of gear teeth, as it seems to last only until certain highly loaded areas are removed and then ceases. We believe that these highly loaded areas should be removed by the gear manufacturer because the slugs dislodged by pitting may further damage the gear or its supporting bearings. Pitting destroys tooth form and may, by so doing, disturb angular velocity resulting in increased tooth impact loads. Uniform angular velocity is important on strip mill pinions, especially on finishing end. A slug between the teeth or any interruption of relative roll velocities may mark the strip at each such interruption.

As mentioned by Mr. Schmitter, when pitting begins to spread to parts other than those adjacent to the pitch line, it generally heralds short life. When new gears pit badly, there are often anxious weeks spent waiting to see whether it will cease or continue to spread. For these reasons, it seems that continued effort to prevent pitting is justified.

I deeply appreciate the interest shown by those taking part in the discussion and although we do not agree on all points, it is hoped that sufficient interest has been aroused to motivate future papers on the subject and that they will contain more detailed information than I was able to present.

MAUGER DISCUSSION

(*Continued from page 49*)

the solving of these problems, there remains the fact that the operators have a job to do also.

I remember when in 1924 Moultrop, of Boston Edison, stepped out for high pressure, engineers all over the country laughed and said, "Well, let Moultrop be the pioneer, we don't want anything like that in our plant," but when he got through he read a paper at the A.S.M.E. where he said that once they got the right operators, and took proper care of the feedwater, it was not any more difficult to run the high pressure boilers than it was the 400 lb. pressure boilers.

On the other hand we have all got to admit that any one having to do with high pressure, high temperature boilers must be alive to the fact that intelligent operation is required. Twenty years ago this was not so. People thought a boiler should turn out steam without much care on the part of the operators. We have all learned that this cannot be done with modern equipment. Today the question of feedwater must be gone into very carefully.

There are many blast furnaces in the country, but outside of Great Lakes Steel and Ford there are practically none in the Detroit section. Your problem is, therefore, quite different from the plants where they have a tremendous amount of waste fuel available such as Tennessee, Colorado and the plants in the Pittsburgh, Cleveland and Youngstown areas. These waste fuels must be burned. In the old days they burned it any old way; they did not care if they got 50 per cent efficiency or not. They bought strings of boilers—a tremendous amount of heating surface to do a small amount of work per unit and when the boilers fell to pieces they bought more.

I think Weirton represents typically what is going to be the trend in modernization where increasing electrical power demand necessitates more steam and electric generating capacity, more particularly where purchased fuel cost becomes an important consideration or where it is impossible to get an attractive rate from a public utility.

SECTION ACTIVITIES

BIRMINGHAM DISTRICT SECTION

October 28, 1940

"Latest Developments in Electric Welding in the Steel Industry," by E. W. Forkner, *Chief Engineer,* Federal Machine and Welding Company.

November 25, 1940

"Synthetic Rubber and Rubber in Industry," by N. A. Nigosian, *Plant Engineer,* Goodyear Tire and Rubber Company, Gadsden, Alabama.

CLEVELAND DISTRICT SECTION

November 4, 1940 (at Cleveland, Ohio)

November 6, 1940 (at Youngstown, Ohio)

"Shell Forgings," by J. H. Hopkins, Salem Engineering Company, Salem, Ohio.

CHICAGO DISTRICT SECTION

November 13, 1940

Subject to be announced.

DETROIT DISTRICT SECTION

October 8, 1940

"Air Cleaning for Steel Mill Applications," by G. F. Begoon and G. E. Stoltz, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

November 12, 1940

"The Hot Coil Conveyor," by J. E. McBride, *Vice-President,* Palmer-Bee Company, Detroit, Michigan.

PHILADELPHIA DISTRICT SECTION

November 2, 1940

"The Sawing of Metals," by C. M. Thompson, Henry Disston and Sons, Inc., Philadelphia, Pennsylvania.

PITTSBURGH DISTRICT SECTION

October 21, 1940

"Systematic Inspection and Maintenance of Steel Plant Electrical Equipment," by W. A. Perry, *Superintendent of Electrical and Power Departments,* Inland Steel Company, Indiana Harbor, Indiana.

November 18, 1940

"Developments in Forging Practice," by John L. Young, *Manager,* Machinery Sales, United Engineering and Foundry Company, Pittsburgh, Pennsylvania.

The Treatment and Use of WATER in CIRCULATING SYSTEMS

By W. P. HILL, *Steam Engineer*

BETHLEHEM STEEL COMPANY

SPARROWS POINT, MARYLAND

Presented before A. I. S. E. PHILADELPHIA DISTRICT SECTION, March 2, 1940

▲ IN every large industrial plant fresh water is an absolute necessity, especially so in the production of steel, and in many cases it is either costly or scarce. In the Maryland Plant of the Bethlehem Steel Company the only source of fresh water is from subterranean streams. Therefore, it is essential to give a great deal of study to the most efficient means of using and re-using it.

The following problems are developed and studied carefully in the case of each mill or unit:

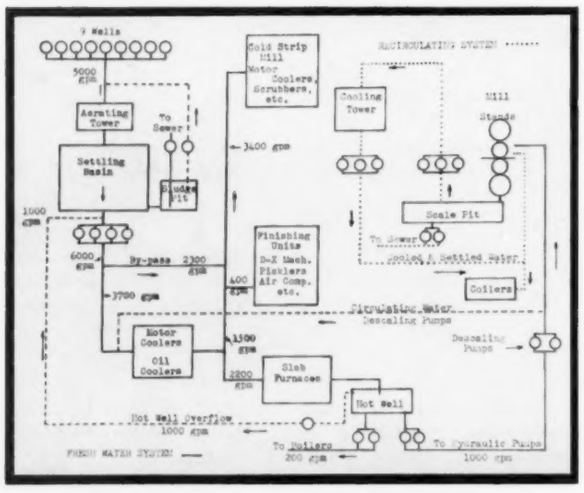
1. What is the quantity of water required, where can such quantity be obtained and how dependable is its source?
2. What treatments are necessary for the available water, cost of the various treatments, and the cost of the equipment to handle the treated water?
3. What are the most efficient distribution and order of re-use, considering the chemical and physical compositions?
4. If a recirculating system can be used, what type of treatment is necessary?

As an example, I shall give you a description of the methods used in treating and handling the water used by the 56 in. continuous strip mill at our Maryland Plant. When this mill was planned, the problem of supplying 21,287 gal. of water per min. was met by the addition of only 4,232 gal. per min. or less than 20 per cent make-up.

From Figure 1, showing the schematic diagram of a section of this fresh water system, you will note the series of performances the water accomplishes before being lost.

The fresh water is pumped from subterranean streams at 235 ft., 335 ft. and 660 ft. by means of turbine electric deep well pumps. The water is of the following analysis which you will note contains too much iron and is too high in acid to be of use as is.

FIGURE 1—Schematic diagram of a section of water distribution system.



Raw Water

CO_2	Methyl orange alkalinity	pH	Fe	Cl	Total hardness	SiO_2	SO_4
47	23	5.9	12	24	19	8	16

Treated Water

Phenolphthalein alkalinity	Methyl orange alkalinity	pH	Fe	Cl	Total hardness
4.3	30	7.9	3.0	24	35

This is conditioned by pumping direct from the deep wells into the top of an aerating tower. The water then flows by gravity through three rolling mix flocculators (Figure 3). Lime and a coagulant are fed into the first flocculator by an automatic feeder controlled by an electric flow meter. At this point the pH is raised to

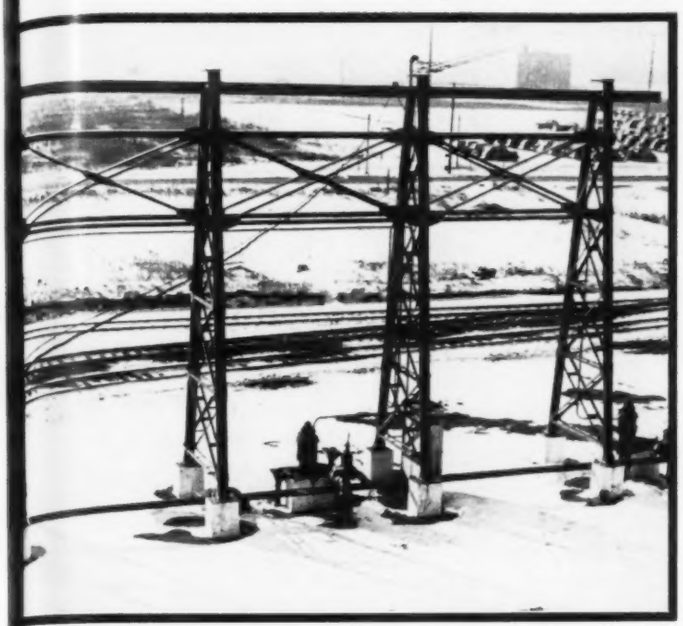


FIGURE 2—View showing installation of electrically driven deep well turbine pumps.

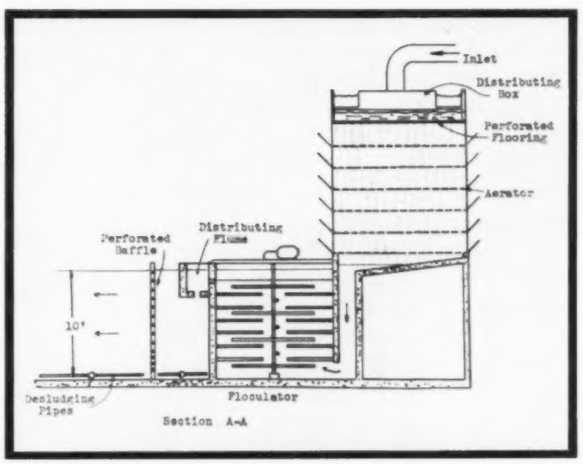
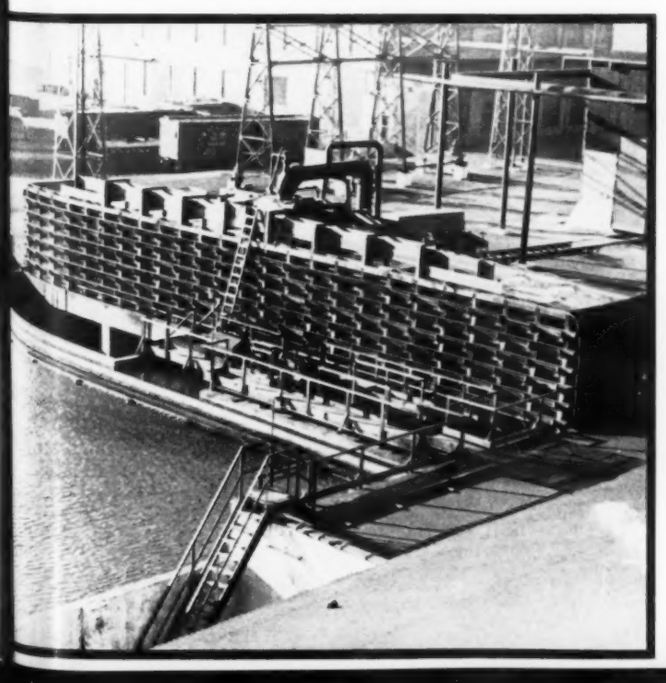


FIGURE 3—Sketch showing aerating tower and treating tank used for conditioning water from deep wells.

FIGURE 4—View of aerating towers, with settling basin in foreground.



approximately 8.0 which requires approximately 22 parts per million of lime. The most efficient floc for iron removal has been found with this alkalinity and 11 parts per million of clay.

The water from the flocculators passes through a special distributing flume and baffle into an 80 ft. x 84 ft. x 10 ft. settling basin, the bottom of which is completely covered with desludging pipes (Figure 5). It is very important to see that there are no high velocities or turbulent flows from the rolling mix flocculator to the outlet distributing baffles or the floc will be broken up, thus decreasing the capacity of the basin. The desludging system discharges into a sump from which the water is reclaimed and the heavy sludge is passed to the sewer. This saves 70,000 gal. per day. The effluent from the settling basin contains approximately 3.0 parts per million of iron and is now suitable for all uses with the exception of the boilers. The boiler water has the additional treatment of a sand and gravel filter and zeolite softening. To protect all the pipe lines and steel equipment from pitting by oxygen, the alkalinity is raised and carried so until a thin, smooth efficient coating of calcium carbonate is laid down. Every few months samples of the pipe lines handling this water

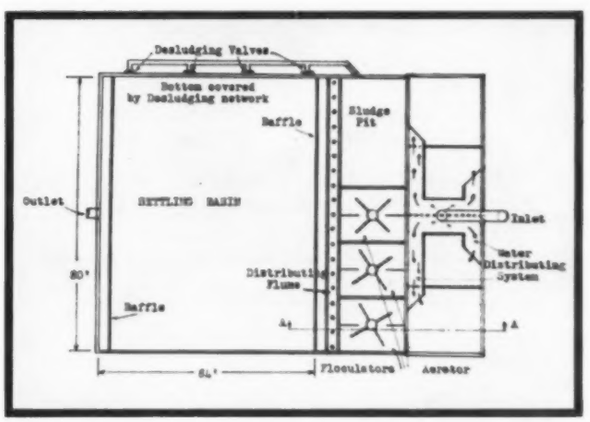


FIGURE 5—Plan view of settling basin treating tanks, and aerating tower.

are removed and inspected to see if the protective coating is of the proper thickness. It is necessary to check samples from both the hot and cold water lines as the hot water lines may have the proper coating while the cold water lines may not.

The treated water is handled by four 2,000 gal. per min. pumps, two electric and two steam turbines, which discharge direct into the main supply at 52 lb. pressure. Approximately 3,700 gal. per min. pass through motor coolers and 2,200 gal. per min. of this passes on through the slab furnaces. The slab furnaces discharge into a hot well from which the boilers and hydraulic descaling pumps receive their water; the remaining water in the hot well passes back into the settling basin suction line. The remaining treated water is re-used in many places throughout the mill, too numerous to try to discuss in

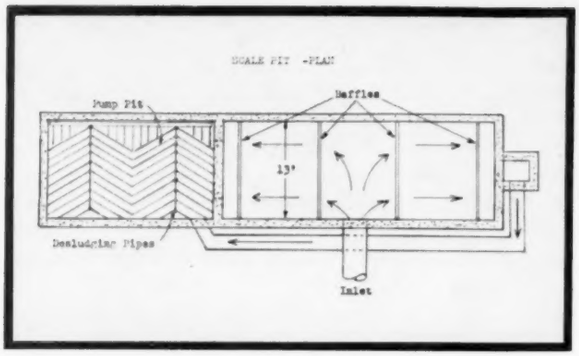


FIGURE 6—Plan view of scale pit, from which water is taken, after settling to the cooling tower.

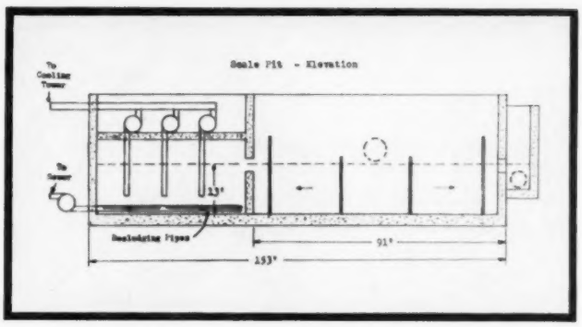
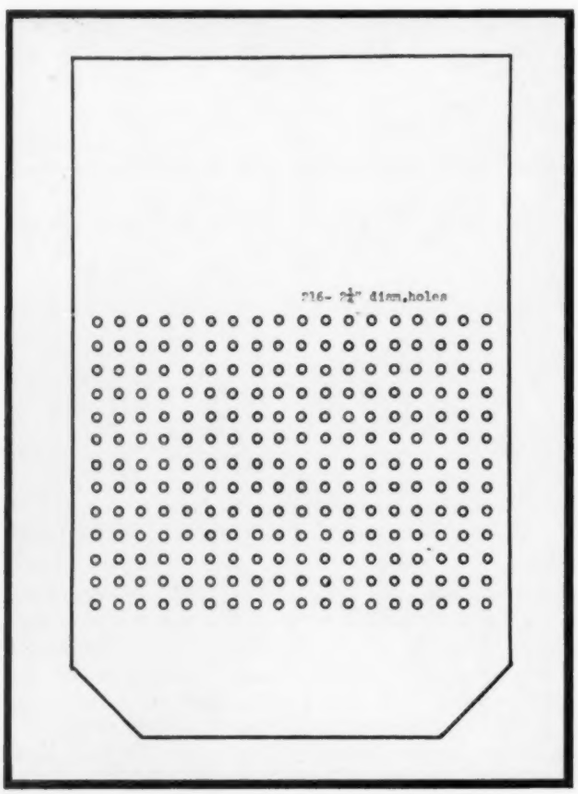


FIGURE 7—Elevation of scale pit, showing arrangement of baffles and desludging pipes.

detail at this time; however, I shall mention a few of the re-uses such as coolers for electric equipment, oil coolers, air compressors, normalizing furnaces, DX machines and various mills. Thus, the warm water received at the end of the line where the picklers and scrubbers are located cuts down on the steam heating load. The re-using of this water as mentioned provides approximately 3,400 gal. per min. to be supplied from this mill to the adjoining older mills.

FIGURE 8—Perforated baffles of this type afford efficient settling in the scale pit.



The water for the hydraulic sprays is taken from the hot well by two 2,000 gal. per min. 110 ft. head pumps discharging into two 1,200 gal. per min. pumps of 1,000 lb. discharge pressure. To insure good surface on the finished strip, hydraulic descaling sprays are located ahead of No. 1, No. 2 and No. 4 roughers and a double spray is placed between No. 2 scale breaker and No. 5 finisher. The descaling water flows into the scale pit, which under normal conditions is sufficient make-up to the circulating system. To prevent the hydraulic pumps from overheating whenever the hydraulic sprays are off, the pump by-passes approximately 650 gal. per min. into the main treated water system.

The circulating water is pumped to the mill by three electrically driven 5,000 gal. per min. pumps at 52 lb. pressure. This cooling water is sprayed on the rolls of each stand at approximately 650 gal. per min. Experience has proven that with an increase in the spray pressure, the same quantity of water will absorb considerably more heat; we assume this is due to better atomization or exposing more surface for heat absorption.

All the water used on the mill rolls and runout table, or about 9,000 gal. per min., flows to a two-way scale recovery and settling pit. The scale pit is 153 ft. long and 13 ft. wide with the average water depth of 13 ft. The water enters the scale pit in the center and flows north and south through perforated distributing baffles and screens. An overflow baffle prevents pulling down the water level in the scale pit, thus maintaining a low velocity of water through the scale pit at all times (Figure 6). This intake method and distribution procedure permit a much larger quantity of water to flow with efficient settling. The perforated baffles are of special interest (Figure 8).

The principle of operation is that with a differential of say 1 in. or 2 in. between the water levels on each side, each hole acts as an individual orifice and each hole passes the same amount of water as each has the same differential head across it. This design gives an even distribution over the entire width and depth, preventing short circuiting and high velocities. This scale pit operates very efficiently with the low uniform velocity

of 4 ft. per min. and removes 39 lb. of wet scale per ton of steel rolled.

At the south end of the scale pit the entire floor is covered with desludging pipes. The desludging equipment is connected to the suction of two 2,500 gal. per min. pumps that operate automatically on high water. Located directly over the desludging equipment are three 5,000 gal. per min. pumps, duplicates of those supplying the circulating water. These pumps discharge direct into the top of the cooling tower.

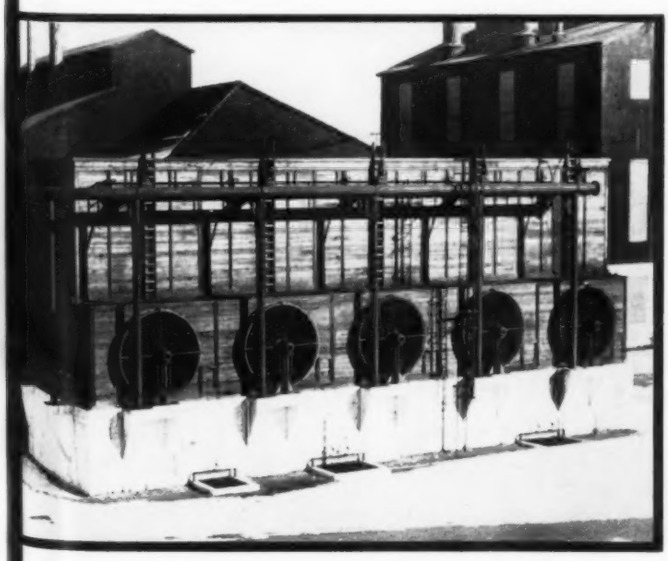
Before discussing this cooling tower, let us outline the fundamental considerations for the cooling of water by evaporation.

1. A large amount of water surface, either in drops or wetted surface.
2. The wet bulb temperature, which is a function of the dry bulb temperature, and relative humidity. (The wet bulb temperature is the absolute lowest limit to which water can be cooled by evaporation. In practice, this temperature can never be reached.)
3. The quantity of air coming in contact with the water surface, its time of contact and its relation to the quantity of water cooled, known as the air-water ratio.
4. The velocity with which the air scours the water surface.

The cooling tower used is a 10,667 gal. per min. forced draft type, having a cooling range from 100 degrees F. to 85 degrees F. with a wet bulb temperature of 75 degrees F. The tower is made up of ten cells, each 16 ft. by 22 ft. by 24 ft. high arranged in two rows of five, back to back. Each cell is equipped with a 10 ft. special axial flow fan.

The water distributing system, as shown in Figure 10, is of the trough and gutter type. Each cell is provided with a main trough inlet which feeds the water to the gutters in which are located the downtake tubes. The water from the downtake tubes discharges into metal discs and is distributed over the entire filling material of the tower. This construction permits practically unlimited flexibility without impairing the effective distribution of water over the full area of the cooling tower.

FIGURE 9—The forced draft cooling tower, composed of ten cells, has a capacity of 10,667 gal. per min.



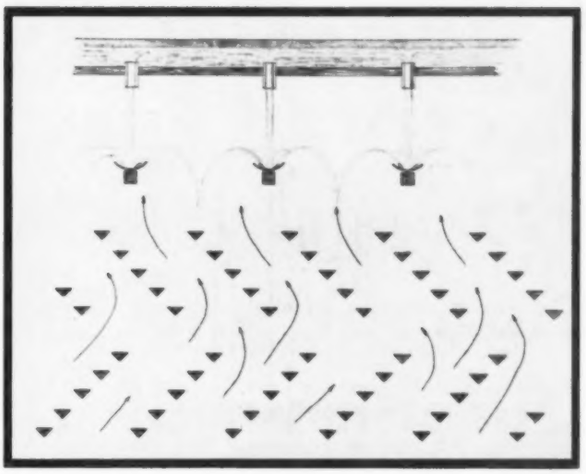


FIGURE 10—Sketch showing water distributing arrangement at top of cooling tower.

The filling material is made up of a great number of wooden triangular sections. Each section is constructed on a 45 degree angle and staggered one above the other. This construction results in a free area to which the upward moving air can pass with a minimum of resistance.

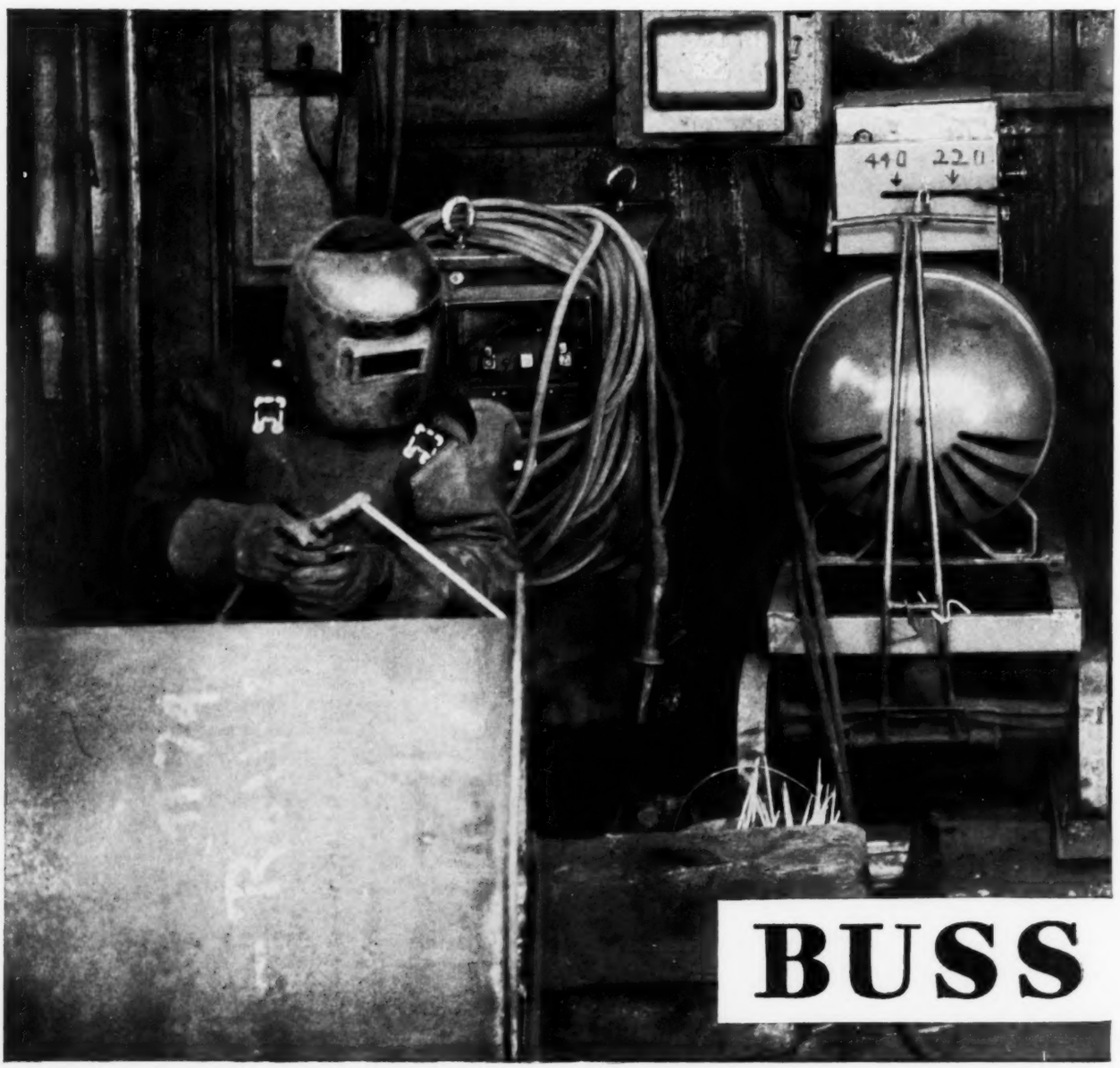
The water rains freely from the filling section of the tower to a sloped roof falling to the outside. It then passes through a perforated wooden distributing baffle into a settling basin. The bottom of the settling basin is completely covered with desludging pipes for removing the fine scale carried to this point. The flow rate in this settling basin is 0.9 ft. per min., which gives excellent results under normal conditions. The reason I mention normal conditions is that a small quantity of oil will alter its efficiency to a marked extent. The water passes from the ten settling basins through perforated concrete walls into a common discharge tunnel supplying the circulating pumps. This water contains only 300 parts per million total solids and is at the required temperature ready for another cycle of the circulating system.

The study of the most economical water supply for the Maryland Plant hot strip mill, based on the fundamentals briefly outlined at the beginning of this paper, has resulted in the installation of the system which has been described. The only losses are those which occur on the mill coilers, for desludging, evaporation, and a very small quantity for general use.

(*Please turn to page 66*)

"When Our Welders Started, We Accepted Fuse Blows as a Necessary Evil . . . But BUSS Fuses Stopped the Blows and Changed Our Viewpoint"

So reports, H. K. ABBOTT,
ELECTRICIAN FOR JAMES RUSSELL BOILER WORKS, BOSTON, MASS.



"HERE WAS OUR SITUATION"...

continues Mr. Abbott, "We use a number of 20 h. p. 220 volt 3 phase portable welders for welding steel plates. They are fed from ordinary disconnect switches located around the plant. 100 ampere fuses, the largest size we felt would give us protection, blew frequently —about six times a week—when the welders were started.

We accepted these production interruptions as a necessary evil we had to tolerate to get safe protection.

In July of 1939 we replaced old fuses with BUSS Super-Lag fuses. We immediately noticed a material reduction in the number of blows. When we checked the records two months later we were astonished to find that we had replaced only six BUSS links.

BUSS fuses stopped our needless blows and changed our viewpoint on the matter of electrical protection."

Why should any plant be crippled by shutdowns that can be avoided?

Production or operating interruptions are always costly—but they are utterly wasteful when caused by the needless opening of protective devices.

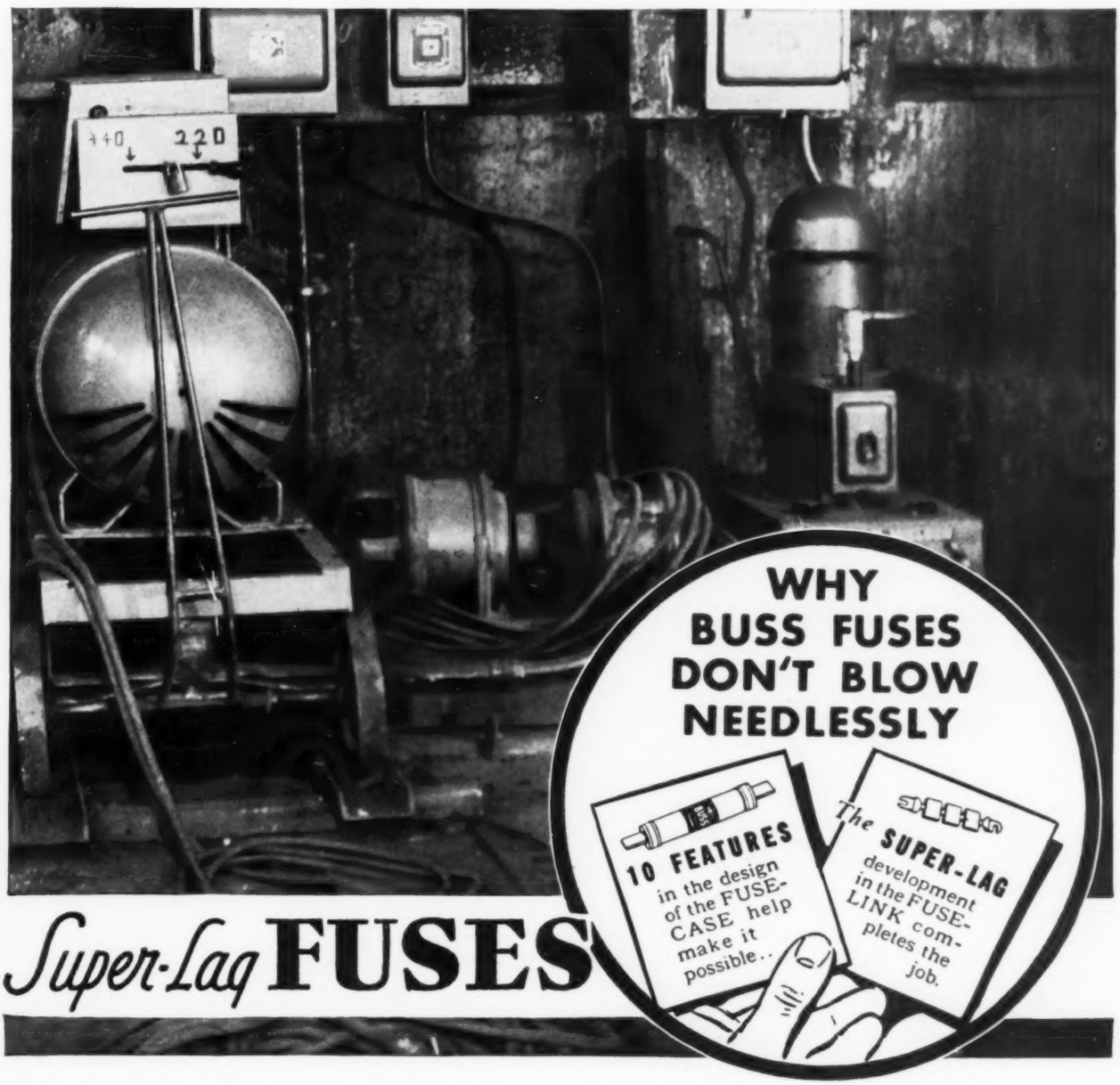
Right here is where BUSS Super-Lag fuses come in to help you stop entirely or greatly reduce such wasteful shutdowns.

In the first place, the design of the BUSS Fuse-Case is such that it prevents needless blows by positively guarding against poor contact developing within the fuse itself. This eliminates much excess heating that so often blows ordinary fuses.

Secondly, the Super-Lag feature in the BUSS Fuse-Link gives BUSS fuses a time-lag long enough to hold most harmless overloads or starting currents—as witness by the experience of Mr. Abbott.

Even if you are but remotely interested in plant operation or maintenance, it will pay you to investigate—and if BUSS fuses are not being used throughout your plant—see that the men responsible for the specification and purchase of fuses are made aware of the difference between ordinary fuses and BUSS Super-Lag fuses.

If you care for detailed information, write for Bulletin Rcs. Bussmann Mfg. Co., University at Jefferson, St. Louis. *Division of McGraw Electric Company.*



DISCUSSION

PRESENTED BY

N. C. BYE, *Chief Engineer,* Henry Disston and Sons, Inc., Philadelphia, Pennsylvania.

W. P. HILL, *Steam Engineer,* Bethlehem Steel Company, Sparrows Point, Maryland.

W. W. HODGE, *Industrial Fellow,* Mellon Institute of Industrial Research, University of Pittsburgh, Pittsburgh, Pennsylvania.

H. J. DIBBLEE, W. H. and L. D. Betz Company, Philadelphia, Pennsylvania.

H. M. RIVERS, *Chemical Engineer,* Hall Laboratories, Inc., Philadelphia, Pennsylvania.

F. C. SCHOEN, *Assistant to Plant Engineer,* Midvale Company, Nicetown, Philadelphia, Pennsylvania.

N. C. BYE: What percentage of the water which goes through the mills is reclaimed?

W. P. HILL: The recirculation system recirculates ten thousand gal. per min. The entire system reclaims 80 per cent.

W. W. HODGE: Mr. Hill's excellent paper contains much information of special interest to me. I would like to ask a question, because I have done considerable work on water purification for industrial as well as municipal purposes both before and since coming to Mellon Institute. I was wondering about the precipitate you get from the bottom of the precipitators. Have you ever made any investigations as to its composition and possible uses?

W. P. HILL: We have been making tests on this precipitate as to using it as a coagulant.

W. W. HODGE: I was much interested in the discussion of the effects of the differences between the wet bulb and the dry bulb temperatures in the cooling towers. That was one of the factors, so it was stated, which caused difficulties in the operation of the Butler-Little process for treatment of waste pickle liquor. During hot weather there were days when there was not a sufficient differential between the dry and wet bulb temperatures of the air blown through the spray cooling, or reclamation tower to cause very much copper as to precipitate from the sprayed waste pickle liquor. So the company constructed an air-conditioning unit at the base of the tower and started drilling some wells to obtain sufficient cold water for the proper operation of the air-conditioner and reclamation tower. They hoped to obtain a good quality well water, which after cooling the air passing through the air conditioner could then be used for other purposes in the steel mill or power plant. However, the water from the first well drilled was high in total solids, fixed mineral matter, and some of the constituents in the water would hydrolyse producing acid action thus causing corrosion of equipment. Hence, the company officials figured they might be losing money to drill more such wells. The point I wanted to emphasize is that the reclamation tower did not operate satisfactorily at times during the summer months for reasons quite similar to those discussed by Mr. Hill.

H. J. DIBBLEE: I was very much interested in Mr. Hill's paper. There was one thought that occurred to me. It was stated that you frequently inspect the pipe lines throughout the plants to see if the calcium carbonate film has been deposited. Have you ever attempted to control the calcium carbonate film by calculating and controlling the "saturation pH"? Such a method of positive control is definitely possible at the present time and is yielding excellent results in wide-scale practice. It would be interesting to know if you have attempted to control on that basis.

W. P. HILL: You can't control it—one part of the mill will have hot water and another part cold water. The only thing you can do is just take samples and check it periodically.

H. M. RIVERS: One particular problem at the Maryland Plant of Bethlehem Steel Company is prevention of corrosion and scale deposition in the cooling water system. Corrosion is checked by feeding enough lime to keep the pH value above a certain point, but this brings in trouble with calcium carbonate scale, especially if the pH is carried too high. This is a water problem in which my company is particularly interested at present. We have found that a surprisingly small quantity of sodium hexametaphosphate will completely prevent deposition of calcium carbonate scale, even though a considerable amount of caustic alkalinity is found necessary to prevent corrosion in the pipe lines. Treatment requires only one or two pounds of chemical in a million pounds of water—only a small fraction of what would be required to soften the water entirely—yet the result is quite complete. The metaphosphate has a further action in suppressing corrosion of the iron and subsequent accumulation of ferric hydroxide, or rust; and right now we are giving thought to this particular application at the Maryland Plant.

I mention this here because "red water" and pipe line corrosion are very common evils which must be corrected somehow; furthermore, many plants do have water high in temporary hardness or have water treated with lime for softening or pH adjustment, and in either case there is the inevitable problem of calcium carbonate precipitation where such a water has to be heated. Metaphosphate has proven to be very effective in tackling these problems, and I thought some of you gentlemen might be interested to know that.

F. C. SCHOEN: I am wondering, in connection with the use and re-use of water, about all these desludging pipes at the bottom of the tanks; is there much trouble keeping these pipes opened up, or do you have to have some arrangement for blowing them back? We have an arrangement on wells and sumps where you have to pump them out and start shoveling. If we put in some sort of desludging apparatus, it might be beneficial.

W. P. HILL: It depends on the man desludging. It can be desludged every two hours and in some of the places it is desludged more often than that. There is no trouble in plugging up, however—of course, it depends on the amount of solids.

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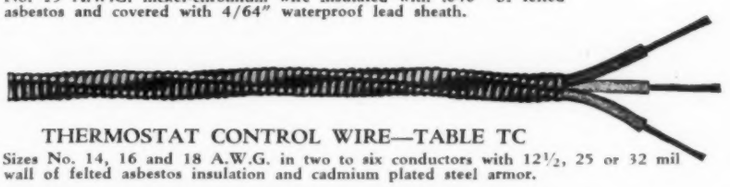

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Sizes No. 14, 16 and 18 A.W.G. in two to six conductors with 12½, 25 or 32 mil wall of felted asbestos insulation and cadmium plated steel armor.

A multi-conductor control wire for low voltage intercommunicating, signal and temperature control systems. Its lifetime insulation and metal braid armor will give you troubleproof circuits.

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600 VOLT A.V.C. BOILER ROOM WIRE—TABLE C

Sizes No. 18 to No. 0000 A.W.G. This construction for sizes 18 to 8, sizes 6 to 0000 have another felted wall next to the conductor.

For lighting and control circuits exposed to heat and moisture, oil, grease, fumes or fire hazard, such as exist around furnaces, ovens, lehrs, soaking pits, boilers, etc., this widely-used A.V.C. construction is ideal. Also for locomotive panel wiring and for switchboards on which an asbestos braided wire is required.

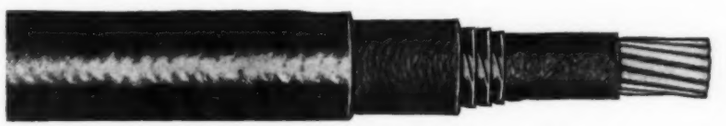
*

600 VOLT ALL-ASBESTOS RHEOSTAT CABLE—TABLE R

Sizes No. 18 A.W.G. to 2,500,000 CM insulated with a heavy wall of felted asbestos and a rugged asbestos braid. Finished in black, white or colors.

Use this power and rheostat cable or Table A, All-Asbestos Rheostat Wire for wiring rheostats, switchboards, elevator and locomotive control panels and electrical equipment exposed to heat, fumes or fire hazard. Also for general open wiring in hot locations.

*

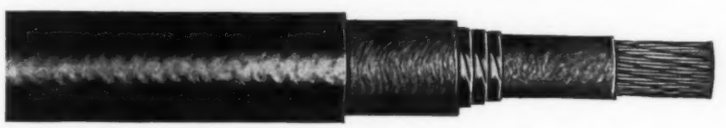


600 VOLT A.V.C. POWER CABLE—TABLE E

Sizes No. 18 A.W.G. to 2,500,000 CM insulated with laminated felted asbestos and varnished cambric, and asbestos braid. Other constructions for service voltages up to 8000.

This cable is recommended for power circuits and hot-spot wiring in or around boiler rooms, ash pits, steam tunnels, soaking pits, tenter frames, glass plants, steel mills, etc. The asbestos and heat-sealed varnished cambric construction has ample moisture resistance and withstands high temperatures indefinitely without failure.

*



600 VOLT A.V.C. MOTOR LEAD AND APPARATUS CABLE—TABLE L

Sizes No. 18 A.W.G. to 1,000,000 CM insulated with two walls of felted asbestos and a high-dielectric heat-sealed insert, covered with heavy asbestos braid.

Heatproof, fireproof, greaseproof and oilproof, this cable will not dry out and crack, won't burn or carry flame, and will remain permanently flexible. For coil connections, motor and transformer leads where extreme heat and fire hazards are encountered as in steel mills, boiler rooms, etc.

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600 VOLT A.V.C. CONTROL CABLE

In one to 19 conductors. Standard stranding A.W.G. No. 12—19/25 and No. 9—19/22. Other strandings furnished to order.

Designed for use under conditions too severe for control cables with other types of insulation which deteriorate rapidly when exposed to high temperatures. Operates without failure under the attack of heat, oil, grease or corrosive fumes and is suitable for installation either open or in conduit as it has ample moisture resistance.

Also refer to Electrical Contracting and Electrical World Buyer's Reference Editions.

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▲ "Unitrol" represents a new engineering idea in motor control installation. Designed and manufactured by Cutler-Hammer, Inc., this latest development permits all needed types of control devices to be organized in locker-like motor control centers instead of the usual "pillar and post" method of mounting.

The standardized construction allows quick building up of any "Unitrol" control center to meet present requirements—and without special engineering. Future changes due to expansion, shop layout changes, etc., are quickly and easily taken care of by adding or removing sections, or by replacing the unit controllers. This feature—pre-engineered flexibility—will be of special value in the present period of industrial expansion for national defense . . . building new plants, remodeling and expansion of present facilities.

With "Unitrol" construction standard motor control units are mounted in standardized cubicle sections. These sections are made in thirty-two sizes; eight widths, four heights (one depth) —for mounting any desired combination of units. Standard units can accommodate controllers, disconnect switches and accessories as required. Control units can be mounted in both front and rear of the section giving double sided construction and an economy of space hitherto unknown. The sections may be installed in a straight line, an L-shape or a U-shape in which case it literally forms its own control room.

Units are assembled either with all wiring busses, supports, terminals and interconnections already made, or with provisions for wiring it on the job.

Blank steel panels are furnished for any unused sections. Pushbuttons, meters and other accessories may be mounted on the blank panels. A door swing-out feature facilitates wiring and change-overs.

UNION DRAWN STEEL EXPANDS GARY PLANT

▲ Expansion of the Union Drawn Steel Division, Republic Steel Corporation at Gary, Indiana, was recently announced. The contract has been let and work will be started immediately on expanding the finishing and producing building, making additions to the rough stock buildings, and rehabilitating an existing building for the installation of new annealing furnaces.

The new buildings will consist of one 300 ft. by 85 ft. and one 150 ft. by 150 ft., properly equipped for handling rough and finished materials.

The construction of these additions will be under the general supervision of George E. Yarnold, superintendent of the Union Drawn plant at Gary.

SOUTH WORKS INCREASES ARC FURNACE CAPACITY

▲ Carnegie-Illinois Steel Corporation will increase its annual electric furnace capacity by approximately 100,000 net tons with the installation of two new electric furnaces at the South Chicago, Illinois, plant. Work has begun on installation of one 60-ton furnace, rated at 13,000 kw., and on a 30-ton furnace, rated at 10,000 kw.

NEW TRUCK ACHIEVES IMPORTANT ECONOMIES

▲ A lifting, carrying, tiering and towing fork truck has been introduced by Clark Tructractor Division of Clark Equipment Company, that is finding wide use among steel mills. It has been found valuable in tiering tin plate in storage and, with its adjustable fingers brought together to serve as a ram, it is said to achieve important economies in handling strip steel and coiled wire. It can be equipped with 84 in. steel ram for handling eight or ten coils at once.

The machine is made in a number of models, with capacities from 2000 to 7000 lb. It travels under load at from 1 to 7½ mi. per hr., tilts its load back 10 degrees for easy riding, ele-

This new fork truck is made in a number of models with capacities from 2000 to 7000 lb.

vates it so it may be piled rafter-high, tilts the load forward 3 degrees for safe tiering. Its chisel point fingers easily pick up cleated loads, skid platforms, etc., and in most cases will pick up loads that have no underclearance at all. Its compactness enables it to negotiate narrow aisles easily.

REPUBLIC WILL IMPROVE SEVERAL STEEL PLANTS

▲ Republic Steel Corporation has announced several important improvements in their plants throughout the United States. Included in these improvements is the installation of a 4-stand, 4-high, 54 in. cold mill at Cleveland, Ohio, in connection with the company's continuous mill operation. This will involve a new crane and auxiliary equipment, and will add substantially to the company's cold rolled capacity. At the strip mill, also, the company will construct additional annealing capacity together with a new warehouse and shipping building.

At Youngstown, Ohio, the No. 4 blast furnace will be enlarged, relined and rebuilt. Included in the improvements for the furnace will be a new skip bridge, skip car, stock house, and new top. With the improvements, the furnace will have an increased capacity of about 10 per cent. Soaking pits will be improved, rebuilt and enlarged in both the open hearth and the bessemer blooming mills.

At Canton, Ohio, work will begin next month on the installation of a fourth 50 ton electric furnace. At Monroe, Michigan, a 4-high, single stand, skin pass mill, with necessary equipment, will be installed to finish coils from the Cleveland strip mill. In Alabama, at the Gadsden plant, soaking pits in the blooming mill will be improved, rebuilt and enlarged.

DEVELOP UNIT ASSEMBLY FOR CURRENT REGULATION

▲ The constant-current regulator, a compact unit assembly comprising a regulator and a controller-protector switch, is the latest development of the Wagner Electric Corporation. It is said that it is the one regulator that has a supply current of unity power-factor when the load also has unity power-factor—and when the load has a lagging power-factor, the input current has a power-factor of approximately the same numerical value but leading.

The regulator has no moving coils but operates from no load to full load, immediately adjusting its output voltage to varying load conditions without surges on the line or lamp circuit and is consequently adjusted instantaneously with changes in load. Due to the extremely low current-draw, the supply-line drop is very small.

NEW TYPE SPRAY NOZZLE FOR DESCALING SYSTEMS

▲ A new type of spray nozzle for both low and high pressure service for spraying either water or oil, has been developed by Trabon Engineering

CHINALAK

has a safety factor of over

300%

The "life" or heat endurance figure for DOLPH'S CHINALAK Black Baking Varnish is over 300% higher than the requirements of the United States Navy Department's specifications. This means that your motors have this added safety factor if the windings are treated with DOLPH'S CHINALAK. Your engineers will readily appreciate that this quality alone makes CHINALAK the ideal varnish for use on glass or asbestos insulated units where normal operating temperatures are high.

Today, more than ever before, motor reliability is a vital factor in steel mill operation. Now, motors must not fail—production schedules can tolerate no interruption. Now, more than ever before, your motors need CHINALAK Black Baking Varnish.

If you are now rewinding motors or contemplate reinsulating your motors for greater dependability, write or wire us collect for any quantity of CHINALAK Black Baking Varnish. We are equipped to make immediate delivery anywhere in the United States.

JOHN C. DOLPH CO.

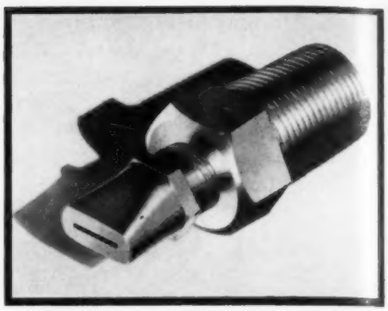
Insulating Varnish Specialists

166A Emmett Street Newark, N. J.

Corporation. This development is the result of several years' research which has included service in various plants of one of the largest steel producers descaling hot steel, where it has proven its value in day in and day out service.

It consists of only two parts, the header adapter is made of stainless steel and the nozzle which fits into it is accurately forged from a solid bar of Monel to the proper shape to give the maximum impinging force over a wide area.

The nozzles are manufactured with several sizes of orifices which are so designed that they effectually control the pattern of the spray, and the delivery is the same thickness at the sides as in the middle. The spray has no feather edges with corresponding reduced pressure. Except for a slight allowance for the extra distance the spray travels, the pressure at the edges of the spray is virtually the same as in the middle. These nozzles in the pressure headers of the descaling system assure the production of cleaner steel with fewer rejections.



This new nozzle is so designed that it effectually controls the pattern of the spray, assuring the production of cleaner steel.

Other features include the use of the nozzles for cooling purposes, and for spraying a fine film of oil on finished stock to avoid corrosion while in transit or storage. There are many other practical applications for this new nozzle.

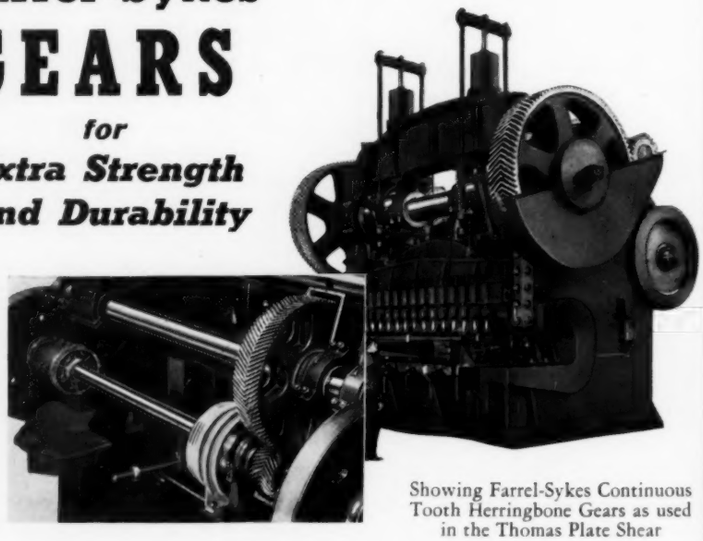
RESISTANCE HEATING FOR WIRE TEMPERING

▲ A new product, electromatic oil tempered spring wire, for special mechanical springs is now being produced by an electric direct resistance method by the Jones and Laughlin Steel Corporation, Pittsburgh.

In contrast to the conventional methods of heating wire to quenching temperatures, either in furnaces or by immersion in molten baths, this new process consists of passing sufficient electric current through the wire to heat it to the desired temperature, much as the coils in an electric toaster are heated by their resistance to the current. The electrical resistance set up in the wire increases its temperature uniformly, and the full cross section of the wire is heated simultaneously to the desired quenching temperature.

The new equipment handles a wide variety of gauges, and is so constructed that wire fed from reels passes first through tension rollers then through a molten electrical contact. From there, the wire passes through a second molten contact, completing the electric circuit through the wire. These contacts are held at a constant pre-

World's Largest Plate Shear Uses
Farrel-Sykes
GEARS
for
Extra Strength
and Durability



Showing Farrel-Sykes Continuous Tooth Herringbone Gears as used in the Thomas Plate Shear

In this giant plate shear, which will cut steel plates up to 2½" thick by 13'6" wide, gears possessing maximum strength and load-carrying capacity had to be used. To secure these qualities, the builder, Thomas Machine Manufacturing Company, equipped this plate shear with Farrel-Sykes Herringbone Gears.

These continuous tooth herringbone gears have a larger number of teeth in contact, which gives them additional strength and ability to carry heavier loads and to withstand shocks, stresses and wear. Wear is retarded by the interlacing of the teeth, creeping engagement and inclined line of pressure. Due to these characteristics, involute profile and correct tooth action are retained as long as the gears last.

The opposed helices of Farrel-Sykes Herringbone Gears balance and absorb axial thrust within the gear member, preventing harmful thrust loads and resultant stresses on other parts of the machinery. Precision generated by the Sykes process, these gears are notably quiet and smooth-running.

Farrel-Sykes Gears are built for every type of service and special units are designed to order. Farrel engineers welcome the opportunity to consult with you on your gear problems.

FARREL SYKES GEARS
FARREL-BIRMINGHAM COMPANY, INC.
366 VULCAN STREET BUFFALO, N. Y.
The Gear with a Backbone

determined temperature, the second also serving as a primary quenching bath from where the wire immediately passes to an oil bath for the final quench. This double-phase quenching feature provides a gradual reduction in wire temperature, preventing the steel from being shocked by a sudden great drop in temperature. Continuing from the final quench through a molten tempering bath, the wire is reheated to give it the desired physical properties and fatigue values. It may then be passed through a light soluble oil bath prior to shipment.

The increasing demand for higher and more uniform physical properties in spring wire is largely responsible for the development of this process, its fundamental advantage being the exactness by which all factors affecting the ultimate quality of the wire are readily controlled. The constant flow of electric current of controlled voltage and amperage fed into the wire, together with the closely regulated speed of the machines, governs heating the wire to within very exact limits. In addition, thermocouples in all contact, quench, and temper baths provide automatic temperature control over these units. The resulting combination of accurate time and temperature regulation makes possible precise control of the heating and quenching cycle.

PHOTOELECTRIC GAGE FOR MEASURING STRIP WIDTH

▲ A new photoelectric gage which gives a continuous and accurate indication of variations in the width of moving steel strip without making contact with the metal has been announced by the General Electric Company. With the new device, the width of the strip can be measured "on the fly" at any point or points in the mill and variations from the required width can be accurately transmitted to any number of desired stations such as the control pulpit, etc. Thus while the strip is moving through the mill, adjustments to the edging rolls can be readily made by the operator to correct deviations from normal width. This continuous method of measurement is in sharp contrast to present practice where the width is checked after the strip is delivered in coils from the coilers. By the time this manual checking is accomplished, several other slabs are in the process of being rolled and on these no correction for width can be made. Obviously, under-gage material means possible rejection while strip excessively wide might have to be side-trimmed. Thus, the continuous indication offered by the new photoelectric gage should make possible substantial savings in time and material.

In operation, both edges of the strip are followed simultaneously by narrow light beams and true indication of its width is given regardless of any sidewise movement of the strip.

NEW ELECTRIC HEATER FOR PORTABLE USE

▲ An attractively finished steel heater case is provided with a new portable heating unit developed by the Edwin L. Wiegand Company. Brack-

PHOTOGRAPH COURTESY THE AMSLER MORTON COMPANY

Rule of thumb steel making

COSTS TOO MUCH TODAY

DAYS when guesswork could be tolerated in a steel mill belong to the past—guesswork costs too much today. Spoilage—lost time and material—inefficient operation—these things rob a plant of profits.

Good steel men no longer depend on a "guess" to control Combustion Conditions in a furnace, an open hearth or a soaking pit. It spoils steel, wastes fuel—cuts down profits.

Hays Combustion Instruments have set the standard for accuracy, dependability and stamina for 38 years. They are as well known in the steel mills and power plants of the country as a monkey wrench. They can be designed to meet practically any requirement concerning indicating, recording and controlling of combustion conditions. Hays Engineer-representatives are located in all the principal cities to help industry in the solution of its combustion problems. They will be glad to serve you. Write to 955 Eighth Ave., Michigan City, Indiana.

The HAYS CORPORATION
SINCE 1901 COMBUSTION INSTRUMENTS AND CONTROL
MICHIGAN CITY, INDIANA, U.S.A.

ADVERTISING PAGES REMOVED

ets are available for permanent wall mounting. Adjustable louvres will direct air in desired direction. "Chromalox Koilstrip" elements within the heater warm air drawn in back of heater and forced out the front by quiet, cadmium-plated fan. Enclosed type electric motor drives fan, without radio interference.

Positive acting thermostatic switch automatically opens heater circuit if normal operating temperatures are exceeded, manually operated reset button will close heater circuit when normal temperatures are restored.

1500 watt heaters are supplied with 10 ft. of heater cord and attachment plug, approved by the Underwriters' Laboratories, to connect to ordinary outlet. All other size heaters are supplied with 10 ft. of heater cord approved by the Underwriters' Laboratories, except 115 volt, 4000 watt heaters, which are supplied with line terminals to be connected to power supply.

OPERATE NEW JUMP MILL AT CONTINENTAL STEEL

▲ A three-high sheet rolling mill for the Kokomo, Indiana, plant of Continental Steel Corporation was recently placed in operation by the Lewis Foundry and Machine Division of Blaw-Knox Company. The mill is of the jump mill type, with only one of its rolls power driven, and is a water controlled semi-breakdown unit. It is equipped with a motor screwdown and automatic roller and catcher tables.

COMPLETELY REDESIGN PRESSURE CONTROLLER

▲ Flexibility of installation, convenience of operation and ease of adjustment are stressed in a completely redesigned industrial furnace pressure controller just announced by the Leeds and Northrup Company. The mechanism is housed in a rigid, die-cast case, similar in appearance to that of most "Micromax" instruments. Although designed primarily for flush-mounting, it can be supplied for surface mounting. Controller and related equipment can be panel-mounted at the factory and shipped, completely connected and wired, to the user's plant.

Built into the controller door is a selector switch and a push-button station. An integral part of the instrument, these space-saving accessories enable the operator to take over on manual control at a moment's notice. Also located at outside of door is a handy control setting knob. Through a window, just below it, can be seen a stationary pointer and a movable dial. Dial is calibrated from −0.05 to +0.15 in. of water. (Pressures up to +.5 in. of water can be accommodated.) A turn of the control setting knob rotates the dial, and adjusts the pressure value.

Adjustments are said to be facilitated by two sets of convenient weights. One set adjusts the zero setting of the instrument's simple mechanical balance; the second adjusts its sensitivity. Both, it is stated, are easy to adjust, and once adjusted, retain their settings reliably.

This new controller, according to the makers, is strongly built, and requires negligible maintenance.

Does Your Insulation Investment Pay a *FULL* Return?

This Surface-Combustion **Soaking Pit, recently installed in the Pittsburgh district, is insulated with 12" x 36" J-M Superex Blocks (shown above) and with JM-20 and Sil-O-Cel C-22 Brick.**

HOW much money you spend on fuel depends to a large extent on the answers to these two questions:

Are you using the *correct insulating materials?*

Are they applied in the *correct thicknesses?*

To assure every saving possible with insulation, it will pay you to call in a J-M Insulation Engineer. Let him study your requirements . . . his specialized technical training and experience will help you trace down and correct sources of heat waste that may otherwise go unnoticed.

From the complete line of J-M Insulations, he can recommend exactly the *material* you need for greatest efficiency . . . exactly the *thickness* you need for maximum returns on your investment.

For full details on this helpful service and facts about the complete line of J-M Industrial Insulations, write to Johns-Manville, 22 East 40th Street, New York, N. Y.

JM Johns-Manville

INDUSTRIAL INSULATIONS FOR EVERY TEMPERATURE ... FOR EVERY SERVICE

Superex ... 85% Magnesia ... JM-20 Brick ... Sil-O-Cel C-22 Brick ... Sil-O-Cel Natural Brick ... J-M No. 500 Cement ... Sil-O-Cel C-3 Concrete ... Marinite

NEW LITERATURE

▲ Ohmite Manufacturing Company has issued a new, comprehensive 96 page industrial catalogue and engineering manual. This book is unlike any other catalogue, in that it is actually an encyclopedia of helpful facts and information on the selection and application of resistors, rheostats, tap switches, chokes and attenuators. It contains a wealth of engineering data, handy reference tables, dimension drawings, illustrations, and a manual of resistance measurements.

Copies of the Ohmite Catalogue No. 40 will be sent to engineers, production managers, purchasing agents, or executives who send their names on company stationery, stating their positions. The address is: Ohmite Manufacturing Company, 4835 Flournoy Street, Chicago, Illinois.

▲ Allis-Chalmers Manufacturing Company has just issued two new bulletins on quick clearing frame mounted high voltage oil circuit breakers for outdoor service. Bulletin B-6003 illustrates and describes the company's very large units available in standard ampere and interrupting capacity ratings from 15 kv. to 69 kv. Bulletin B-6093 covers small units in standard ratings from 15 kv. to 23 kv. Both of these bulletins are well illustrated and fully cover the distinctive features of design which include quick quench ruptors, high speed solenoid operator and accessible control cabinet.

These bulletins may be obtained by writing to the Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin.

▲ Cochrane Corporation has available for distribution a new eight page bulletin covering six different styles of mechanical and electrical operated liquid level meters. Application drawings and technical data are conveniently arranged in sections devoted to each of the various available instruments.

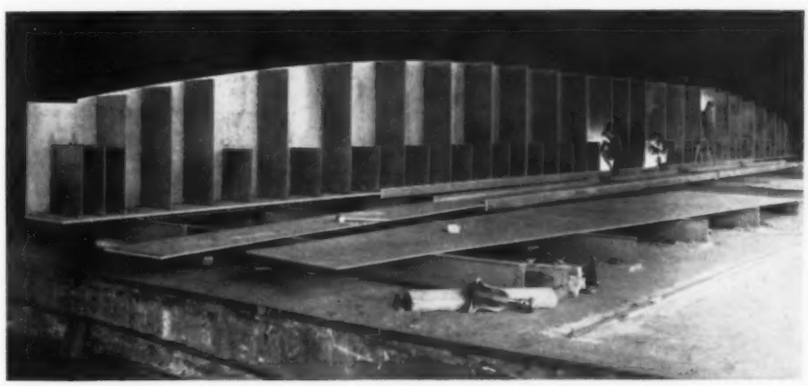
Write to the Cochrane Corporation, 17th and Allegheny Avenue, Philadelphia, Pennsylvania, for copies of Publication 2990.

▲ Holophane Company, Inc., has available for distribution a limited quantity of their newly revised bulletin on "Protective Lighting for Industrial Plants," containing up to the minute data on this type of lighting.

Interested persons should direct their inquiries to Holophane Company, Inc., 342 Madison Avenue, New York.

▲ Westinghouse Electric and Manufacturing Company has available the latest edition of the "Quick Selector" catalogue. This is the second 1940 edition of this book simplifying selection of the correct electrical equipment for any motor, lighting, or feeder circuit. Electrical ratings, physical dimensions, and individual circuit diagrams for the various devices are included, along with accurate and up-to-the-minute price information for every item.

This sixty-four page book may be obtained by writing to the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.



BUILDING THE WORLD'S LARGEST
***All-Welded* CRANE GIRDER**

Here you see a giant all-welded girder for a Cleveland Crane in process. Plates ranging in thickness from $\frac{7}{16}$-inch to $1\frac{1}{4}$-inch are being welded into position. This girder when complete will weigh 45 tons, be 105 feet long and over eight feet high at middle.

This girder will be stronger and more rigid for its weight than possible by any other method of construction.

Note the close spacing of reinforcing diaphragms. These are welded not only to web plates, but also to the top plate — an advantage exclusive with welded girders. The diaphragms are so close that they alone will support the trolley rails without depending on the top plate, thus eliminating possibility of plate cracking.

For really tops in cranes specify —
"CLEVELAND ALL-WELDEDS"

THE CLEVELAND CRANE & ENGINEERING CO.
Wickliffe, Ohio

CLEVELAND CRANES
ALL-WELDED OVERHEAD TRAVELING CRANES
Other products: CLEVELAND TRAMRAIL and STEELWELD MACHINERY

ITEMS OF INTEREST

Julius E. Graf
was appointed assistant chief engineer of the Jones and Laughlin Steel Corporation. Mr. Graf, who was previously vice-president in charge of engineering for the Treadwell Engineering Company, was at one time assistant chief engineer of the Carnegie-Illinois Steel Corporation. In 1939, he became affiliated with the Treadwell Engineering Company, after twenty-eight years' service with the subsidiaries of the United States Steel Corporation. Beginning with the American Sheet and Tin Plate Company, Mr. Graf was chief engineer of that company at the time of the merger with Carnegie-Illinois Steel Corporation. While with the Carnegie-Illinois Steel Corporation he was engaged in an engineering advisory capacity, principally in connection with major projects such as the slabbing mill at Edgar Thomson Works, Braddock, Pennsylvania, and the new Irvin Works at Dravosburg, Pennsylvania.

John E. Mateer,
who has been open hearth melter foreman of Lukens Steel Company, Coatesville, Pennsylvania, has been promoted to assistant open hearth superintendent. Mr. Mateer was born in Middletown, Pennsylvania, in 1892. He went to Lukens in 1907 as door-boy in the open hearth department. He worked successively in the open hearth as second helper and first helper until 1918, when he became a melter in which capacity he continued until his appointment as melter foreman in 1927.

T. T. Watson,
who has been development and service metallurgist of Lukens Steel Company since 1934, has been appointed research metallurgist in charge of all plant research. Mr. Watson was graduated in 1923 from the Royal Technical College, Glasgow, Scotland, with the degree of Associate of the Royal Technical College. He joined David Colville and Sons, largest iron and steel manufacturer in Scotland, as assistant metallurgist immediately after graduation, and served in that capacity until 1925, when he became metallurgist for the Clyde Alloy Steel Company. From 1927 to 1930, Mr. Watson was assistant metallurgist at Dorman Long and Company, England. Since 1930, he has been in the United States as a consulting metallurgist first, and for the last nine years successively as member of the metallurgical department, development and service metallurgist, and now research metallurgist for Lukens Steel Company.

Otto V. Gray,
assistant to general superintendent, Carnegie-Illinois Steel Corporation, Gary sheet and tin division, retired on October 1, after thirty-nine years of continuous service with United States Steel Corporation subsidiaries. Mr. Gray's employment with the subsidiaries began in 1901. He came to the Gary sheet mill in 1911 as superintendent of plate and jobbing mills and remained in this capacity until 1920, when he was made mill superintendent. Nine years later, he became assistant manager of the sheet mill, the position he held until the combining of the Gary sheet and the Gary tin mills on June 1, 1936, at which time he was appointed to the post he held at the time of his retirement.

Harry J. Sweeney
has been appointed chief metallurgist, Youngstown district, Republic Steel Corporation. Prior to joining Republic in 1936 he was assistant superintendent, open hearth department, Carnegie-Illinois Steel Corporation, Homestead, Pennsylvania.

E. A. Schwartz,
for the past seventeen years open hearth superintendent of the Brier Hill plant of the Youngstown Sheet and Tube Company, Youngstown, Ohio, has been named full-time chairman of the Republic Steel Corporation's open hearth committee.

Walter S. Scott,
heretofore assistant superintendent of Republic Steel Corporation's electric weld tube mill, Youngstown, Ohio, has become superintendent of the bessemer department in Youngstown.

JULIUS E. GRAF

J. E. MATEER

T. T. WATSON

W. Richison Schofield, formerly chief engineer of Leeds and Northrup Company, Philadelphia, Pennsylvania, has recently been appointed director of engineering. Mr. Schofield joined the Leeds and Northrup Company in 1916, and since 1928 has held the position of chief engineer. An authority in pyrometry and automatic control, he holds important patents in this field.

W. RICHISON SCHOFELD

John W. Harsch, assistant chief engineer, has been advanced to chief engineer for the Leeds and Northrup Company, Philadelphia, Pennsylvania. Mr. Harsch became affiliated with this company in 1924 and in 1928 became assistant chief engineer. He is largely responsible for the design of various types of heat treating furnaces for the Leeds and Northrup Company.

JOHN W. HARSCH

John F. Quereau was appointed assistant chief engineer for the Leeds and Northrup Company, Philadelphia, Pennsylvania. Mr. Quereau has been with Leeds and Northrup since 1929, and is the inventor of a number of thermocouple and resistance thermometer devices.

Clayton W. Morehead has been appointed assistant superintendent of the open hearth, 40 in., 21 in. and 18 in. mills in Republic Steel Corporation's Youngstown plant. Mr. Morehead joined the corporation in 1933 and in 1934 was named turn foreman, electric weld tube mill.

Wade R. Weaver, since last February superintendent of open hearth and blooming mills of Republic Steel Corporation, Youngstown, Ohio, has become assistant superintendent, open hearth furnaces.

Frank W. Robertson was appointed general manager of both the Ungerer Leveler and the machine tool divisions of the Edward W. Voss Company, Pittsburgh, Pennsylvania. Mr. Robertson was formerly sales manager of the Ungerer Leveler division.

Edgar H. Kern purchasing agent, Weirton Steel Company since 1929, died recently from complications following influenza. Mr. Kern's home was in Steubenville, Ohio. He became associated with the Weirton Steel Company in 1922 in a clerical position in the purchasing department. He became purchasing agent in the spring of 1929, succeeding W. A. Murphy when the latter became secretary of the company.

STATEMENT OF OWNERSHIP, MANAGEMENT, ETC., OF

IRON AND STEEL ENGINEER

(Required by Act of Congress of August 24, 1912)

Name of Publication: *Iron and Steel Engineer*, published monthly at Pittsburgh, Pa. (Report of October 1, 1940.)

Editor: Brent Wiley, Empire Building, Pittsburgh, Pa.

Business Manager: James D. Kelly, Empire Building, Pittsburgh, Pa.

Names and addresses of stockholders holding 1 per cent or more of total amount of stock: None.

BOARD OF DIRECTORS

1940

President, Julius A. Clauss, *Chief Engineer*, Great Lakes Steel Corporation, Ecorse, Detroit, Michigan.

First Vice-President, William A. Perry, *Superintendent of Electrical and Power Departments*, Inland Steel Company, East Chicago, Indiana.

Second Vice-President, Thomas E. Hughes, *Superintendent of Maintenance Department*, Carnegie-Illinois Steel Corporation, Duquesne, Pennsylvania.

Director-at-Large, C. L. McGranahan, *Assistant General Superintendent*, Jones and Laughlin Steel Corporation, Pittsburgh Works, Pittsburgh, Pennsylvania.

Honorary Directors: James Farrington, *Superintendent of Electrical Department*, Wheeling Steel Corporation, Steubenville, Ohio.

E. Friedlander, Pittsburgh, Pennsylvania.

A. C. Cummins, *General Superintendent*, Youngstown District, Carnegie-Illinois Steel Corporation, Youngstown, Ohio.

Past Presidents: C. Clarke Wales, *Vice-President*, Hamilton Bridge Company, Ltd., Hamilton, Ontario, Canada.

L. F. Coffin, *Mechanical Superintendent*, Bethlehem Steel Company, Sparrows Point, Maryland.

Treasurer, F. E. Flynn, *District Manager*, Republic Steel Corporation, Warren, Ohio.

Secretary, J. L. Miller, *Assistant Chief Comb. Engineer*, Republic Steel Corporation, Cleveland, Ohio.

Director, Frank P. May, *Assistant Chief Engineer*, By-Product Coke Works, Carnegie-Illinois Steel Corporation, Clairton, Pennsylvania.

Director, George E. Adams, *Electrical Superintendent*, Youngstown Sheet and Tube Company, East Chicago, Indiana.

Director, L. V. Black, *Electrical Superintendent*, Bethlehem Steel Company, Bethlehem, Pennsylvania.

Director, L. R. Milburn, *Electrical Engineer*, Great Lakes Steel Corporation, Ecorse Detroit, Michigan.

Director, F. M. Sturgess, *Master Mechanic and Chief Electrician*, Wire Works, Tennessee Coal, Iron and Railroad Company, Fairfield, Alabama.

Director, M. J. Conway, *Special Engineer*, Lukens Steel Company, Coatesville, Pennsylvania.

Director, F. W. Lorig, *Engineer for Appropriations and Properties*, American Steel and Wire Company, Cleveland, Ohio.

Director, A. W. Steed, *Superintendent of Maintenance*, American Rolling Mill Company, Middletown, Ohio.

Director, F. L. Gray, *Lubrication Engineer*, Carnegie-Illinois Steel Corporation, Gary Works, Gary, Indiana.

Managing Director, Brent Wiley, Empire Building, Pittsburgh, Pa.

Known bondholders, mortgages and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages or other securities: None.

BRENT WILEY, Editor.

Sworn to and subscribed before me this thirtieth day of September, 1940.

G. WILLIAM JONES, JR., Notary Public

(My commission expires February 9, 1943.)

NEW MEMBERS

Active

J. E. McCarthy
Maintenance Foreman
Rotary Electric Steel Company
Detroit, Michigan

Harold E. Phelps
Electric Furnace Superintendent
Rotary Electric Steel Company
Detroit, Michigan

Thomas J. Peiffer
Mechanical Engineer
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

J. B. Vanderwerf
Chief Shipper
Cold Strip Mills
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

Bruce A. Powell
General Foreman
Continuous Pickler
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

John R. Murphy
Metallurgist
Cold Strip Mill
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

Lester J. Andregg
Assistant General Finishing Foreman
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

Elwood C. Jones
General Foreman, Finishing Department
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

Edwin L. Fisher
Order and Schedule Superrisor
Strip Mill
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

S. C. Faddis
Strip Mill Metallurgist
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

Reese R. Saunders
Superintendent
Order Department
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

F. J. Brandl
Chief Clerk
Cold Strip Mill
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

Stanley J. Kail
Night Superintendent
Jones and Laughlin Steel Corp.
Continuous Cold Strip Mill
Pittsburgh, Pennsylvania

John P. Burr
Hot Strip Mill Master Mechanic
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

Lauson Stone
Assistant to President
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

Warren Murrie
Engineer
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

Geo. S. Monks
Chief Draftsman
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

R. J. McGuigan
Metallurgist
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

Albert J. E. Wilson
Master Mechanic
Eliza Furnaces
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

Jos. J. Shepherd
Junior Draftsman
Carnegie-Illinois Steel Corporation
Duquesne, Pennsylvania

J. W. Helding
Electrical Foreman
76 in. Hot Strip Mill
Inland Steel Company
East Chicago, Indiana

R. J. Tremblay
Comb. Engineer
Bethlehem Steel Company
Seattle, Washington

F. B. Stockton
Industrial Engineer
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

A. L. Thomas
Expeditor
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

John H. Gedeon
Industrial Engineer
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

Harold P. Miles
Mechanical Engineer
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

L. E. Crow
General Foreman
Plate Finishing
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

Louis H. Valette
Mechanical Engineer
Inland Steel Company
East Chicago, Indiana

Chas. L. Watts
Chief Draftsman
Lukens Steel Company
Coatesville, Pennsylvania

W. J. Pattison
Superintendent
Shop and Foundries
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

T. H. Knox
Roller
96 in. Hot Strip Mill
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

Wm. D. Rogers
Hot Mill Turn Foreman
96 in. Hot Strip Mill
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

E. B. Page
Electrical Foreman
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

Wm. L. Witney
Assistant Chief Industrial Engineer
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

James Russell
Industrial Engineer
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

Jonathon Rose
Metallurgist
Universal Cyclops Steel Corporation
Bridgeville, Pennsylvania

Henry C. VanDeventer
Industrial Engineer
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

Fred L. Raum
Superintendent
Mill Order and Shipping Dept.
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

Elof A. Eklund
Normalizer and Pickler Foreman
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

J. L. McCann
Turn Foreman
Electrical Dept., Cold Strip Mill
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

H. S. Iams
General Foreman, Electrical Dept.
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

Chas. W. McQuown
General Foreman
Hot Strip Finishing
Jones and Laughlin Steel Corp.
Pittsburgh, Pennsylvania

Blaine Rush
General Foreman
Electric Construction
Great Lakes Steel Corporation
Ecorse, Michigan

James F. Gulliver
Roll Foreman
Cold Strip Department
Great Lakes Steel Corporation
Ecorse, Michigan

John L. Bowling
General Roll Foreman
Cold Strip Department
Great Lakes Steel Corporation
Ecorse, Michigan

Kenneth M. Freemark
Instrument Technician
Great Lakes Steel Corporation
Ecorse, Michigan

Harry R. Butler
General Foreman
Finishing Department
Great Lakes Steel Corporation
Ecorse, Michigan

Lawrence Hollander
Assistant Chief Inspector
Cold Strip Mill
Great Lakes Steel Corporation
Ecorse, Michigan

William M. Jenkins
Electrical Turn Foreman
No. 2 Open Hearth
Great Lakes Steel Corporation
Ecorse, Michigan

Elmer A. Hand
Mechanical Turn Foreman
Great Lakes Steel Corporation
Ecorse, Michigan

R. V. Lackner
Assistant Planning Engineer
Maintenance Department
Carnegie Illinois Steel Corporation
Duquesne, Penna.

Charles F. Knapp
Bar Mill Turn Foreman
Republic Steel Corporation
Canton, Ohio

Louis N. McDonald, Jr.
Chief Power and Fuel Engineer
Carnegie-Illinois Steel Corporation
Youngstown, Ohio

Harry U. Johns
Mechanical Engineer
Bethlehem Steel Company
Lebanon, Penna.